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THERMAL CONDUCTIVITY OF PARTICULATE MATERIALS: A SUMMARY OF MEASUREMENTS TAKEN AT THE MARSHALL SPACE FLIGHT CENTER

By James A. Fountain, Ronald W. Scott,
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16. ABSTRACT

Thermal conductivity measurements of particulate materials in vacuum are presented in summary. Particulate basalt and soda lime glass beads of various size ranges were used as samples. The differentiated line heat source method was used for the measurements. A comprehensive table is shown giving all pertinent experimental conditions. Least-squares curve fits to the data are presented for $K = A + BT^3$ and $K = A + BT + CT^3$. The latter equation is shown to give a slightly better fit to the data in most cases. In the relatively low vacuum data, the curves $K = A + BT$ and $K = A + BT + CT^2$ were fitted to the data.

EDITOR'S NOTE

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THERMAL CONDUCTIVITY OF PARTICULATE MATERIALS: A SUMMARY OF MEASUREMENTS TAKEN AT THE MARSHALL SPACE FLIGHT CENTER

INTRODUCTION

This report is a summary of approximately 1100 separate thermal conductivity tests of particulate materials conducted in the Space Sciences Laboratory of the Marshall Space Flight Center from 1965 to 1972. The tests were taken under a variety of programs and most of the data have been published previously [1, 2, 3, 4]. A complete description of the method of measurement, the differentiated line heat source, is given by Merrill [5] and Scott and Fountain [6].

Thermal conductivity was measured as a function of sample material, particle size, temperature, bulk density, chamber pressure, interstitial gas, and sample surface loading (which was used to simulate depth). The apparatus used in the tests was the same in all cases except as noted in Table 1, where the measurement was made using the conventional line heat source techniques as described by Salisbury and Glaser [7].

EXPLANATION OF DATA PRESENTATION

Four equations were curve-fitted to each set of data points by a least squares fit routine. They are: $K = A + BT + CT^3$, $K = A + BT^3$, $K = A + B/T + CT^3$, and $K = e^{A + BT}$. The first three equations were taken from the literature and are based on theoretical considerations [2]. The fourth equation was chosen so that a straight line could be curve-fitted to the data when plotted on semilog paper. Table 1 lists the variables for the different test series and gives the figure and table numbers for the data points. Table 1 also lists the values of the standard deviation for each curve fit. The standard deviations are significant only between the four equations curve-fitted to the same data points and not between the different test series without normalization. Graphs of

$K = A + BT + CT^3$ and $K = A + BT^3$ are shown for comparison for each set of data points in Figures 1 through 23. Graphs of $K = A + B/T + CT^3$ and $K = e^{A + BT}$ are not shown, but the A, B, and C coefficients are given in Table 2 for all four equations.

Figures 24 through 27 show the results of thermal conductivity tests taken on the samples in the vacuum range of 6.9×10^2 N/m^2, using CO_2 as the interstitial gas. A straight line $K = A + BT$ and a second-degree polynomial $K = A + BT + CT^2$ were fitted through the data points. The A, B, and C coefficients for these two equations are also given in Table 2.

Tables 3 through 29 give the thermal conductivity and corresponding temperature for each data point.

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TABLE 1. DATA SUMMARY

Figure No.	Table No.	Sample	Particle Size (μm)	Temperature Range (° K)	Density (g/cm^3)	Chamber Pressure		Sample Load (g/cm^2)	Standard Deviations for Curve Fits (X 10^{-5})			
						(N/m^2)	(TORR)		$K = A + BT + CT^3$	$K = A + BT^3$	$K = A + B/T + CT^3$	$K = e^{A+BT}$
1	3	Basalt	37 – 62	179–365	0.79	1.3×10^{-6}	1×10^{-8}	0	0.03	0.03	0.03	0.03
2	4	Basalt	37 – 62	152–367	0.88	1.3×10^{-6}	1×10^{-8}	0	0.05	0.05	0.05	0.05
3	5	Basalt	37 – 62	159–361	0.98	1.3×10^{-6}	1×10^{-8}	0	0.09	0.10	0.10	0.10
4	6	Basalt	37 – 62	140–370	1.13	1.3×10^{-6}	1×10^{-8}	0	0.04	0.08	0.04	0.05
5	7	Basalt	37 – 62	149–370	1.30	1.3×10^{-6}	1×10^{-8}	0	0.05	0.05	0.05	0.07
6	8	Basalt	37 – 62	133–367	1.50	1.3×10^{-6}	1×10^{-8}	0	0.07	0.13	0.07	0.07
7	9	Glass Beads*	30 – 38	118–371	1.58	1.3×10^{-6}	1×10^{-8}	0	0.22	0.22	0.22	0.26
8	10	Glass Beads	30 – 38	124–373	1.58	1.3×10^{-6}	1×10^{-8}	0	0.13	0.13	0.13	0.13
9	11	Glass Beads	590 – 840	190–297	1.50	1.3×10^{-6}	1×10^{-8}	0	0.76	0.76	0.76	0.76
10	12	Glass Beads	590 – 840	208–296	1.50	1.3×10^{-6}	1×10^{-8}	150	2.5	2.6	2.5	2.6
11	13	Glass Beads	590 – 840	178–298	1.58	1.3×10^{-6}	1×10^{-8}	198	0.6	0.6	0.6	0.7
12	14	Glass Beads	590 – 840	131–300	1.58	1.3×10^{-6}	1×10^{-8}	348	1.1	1.1	1.1	1.1
13	15	Glass Beads	590 – 840	199–309	1.58	1.3×10^{-2} N_2	1×10^{-4} N_2	150	1.2	1.6	1.2	1.5
14	16	Glass Beads	590 – 840	129–297	1.58	1.3×10^{-1} N_2	1×10^{-3} N_2	348	0.9	1.5	1.0	1.2
15	17	Glass Beads	590 – 840	204–299	1.58	1.3×10^{-1} N_2	1×10^{-3} N_2	150	1.0	1.4	1.0	1.4
16	18	Glass Beads	590 – 840	215–297	1.58	1.3 N_2	1×10^{-2} N_2	150	1.7	2.1	1.7	2.1
17	19	Glass Beads	590 – 840	176–295	1.51	3.25 N_2	2.5×10^{-2} N_2	0	0.99	1.16	1.01	1.14
18	20	Glass Beads	590 – 840	136–297	1.58	3.25 N_2	2.5×10^{-2} N_2	348	0.6	1.4	0.7	1.2
19	21	Glass Beads	590 – 840	122–296	1.51	5.85 N_2	4.5×10^{-2} N_2	0	1.06	1.07	1.06	1.13
20	22	Glass Beads	590 – 840	224–296	1.58	6.5 N_2	5.0×10^{-2} N_2	0	0.4	1.0	0.4	1.0
21	23	Glass Beads	590 – 840	198–301	1.58	6.5 N_2	5.0×10^{-2} N_2	150	1.0	1.2	1.0	1.2
22	24	Glass Beads	590 – 840	127–297	1.58	6.5 N_2	5.0×10^{-2} N_2	348	0.9	2.1	1.1	1.8
23	25	Glass Beads	590 – 840	191–298	1.58	13 N_2	1×10^{-1} N_2	150	1.3	1.3	1.3	1.3
						(N/m^2)	(mb)		A + BT	A + BT + CT^2		
24	26	Glass Beads	30 – 38	193–305	1.58	6.9×10^2 CO_2	7 CO_2	0	1.3	1.3		
25	27	Basalt	37 – 62	206–318	0.79	6.9×10^2 CO_2	7 CO_2	0	0.4	0.4		
26	28	Basalt	37 – 62	222–304	1.13	6.9×10^2 CO_2	7 CO_2	0	0.6	0.6		
27	29	Basalt	37 – 62	207–365	1.50	6.9×10^2 CO_2	7 CO_2	0	0.5	0.5		

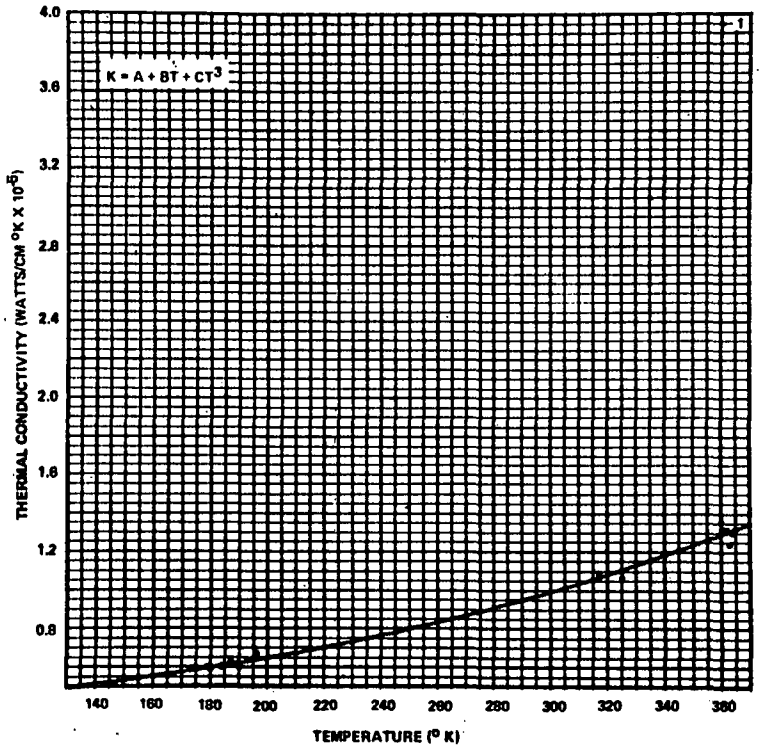
*. Conductivity measured by conventional line heat source method; all others measured by differentiated line heat source. The basalt sample is an Oregon basalt, the source of which is described in Reference 3. The 30- to 38-μm glass beads were manufactured by Microbeads, Inc., and the 590- to 840-μm beads by the Cataphote Corp.

TABLE 2. A, B, AND C COEFFICIENTS FOR EACH CURVE FIT

Figure No.	Table No.	Coefficients for $K = A + BT + CT^3$			Coefficients for $K = A + BT^3$		Coefficients for $K = A + B/T + CT^3$			Coefficients for $K = e^{(A+BT)}$	
		A	B	C	A	B	A	B	C	A	B
1	3	3.011×10^{-6}	1.294×10^{-8}	1.128×10^{-13}	5.086×10^{-6}	1.691×10^{-13}	7.805×10^{-6}	-4.737×10^{-4}	1.380×10^{-13}	-1.280×10^{1}	4.271×10^{-3}
2	4	6.123×10^{-6}	2.551×10^{-8}	1.566×10^{-13}	6.590×10^{-6}	1.666×10^{-13}	6.341×10^{-6}	4.942×10^{-6}	1.693×10^{-13}	-1.252×10^{1}	3.756×10^{-3}
3	5	1.981×10^{-6}	2.640×10^{-8}	5.660×10^{-14}	6.183×10^{-6}	1.808×10^{-13}	9.863×10^{-6}	-6.308×10^{-4}	1.315×10^{-13}	-1.256×10^{1}	3.910×10^{-3}
4	6	3.257×10^{-6}	3.659×10^{-8}	1.204×10^{-14}	8.735×10^{-6}	1.857×10^{-13}	1.457×10^{-5}	-9.140×10^{-4}	1.067×10^{-13}	-1.211×10^{1}	3.177×10^{-3}
5	7	1.202×10^{-5}	2.141×10^{-9}	2.333×10^{-13}	1.236×10^{-5}	2.432×10^{-13}	1.264×10^{-5}	-4.677×10^{-5}	2.398×10^{-13}	-1.170×10^{1}	2.820×10^{-3}
6	8	8.203×10^{-6}	5.412×10^{-8}	8.140×10^{-14}	1.642×10^{-5}	3.430×10^{-13}	2.454×10^{-5}	-1.291×10^{-3}	2.278×10^{-13}	-1.146×10^{1}	3.080×10^{-3}
7	9	1.115×10^{-5}	-1.559×10^{-8}	5.383×10^{-13}	8.627×10^{-6}	4.684×10^{-13}	6.461×10^{-6}	3.351×10^{-4}	4.984×10^{-13}	-1.213×10^{1}	4.687×10^{-3}
8	10	2.965×10^{-6}	2.757×10^{-8}	2.502×10^{-13}	7.676×10^{-6}	3.709×10^{-13}	1.154×10^{-5}	-6.968×10^{-4}	3.220×10^{-13}	-1.255×10^{1}	5.396×10^{-3}
9	11	8.968×10^{-6}	1.678×10^{-8}	1.651×10^{-12}	1.173×10^{-5}	1.738×10^{-12}	1.452×10^{-5}	-5.103×10^{-4}	1.695×10^{-12}	-1.223×10^{1}	8.249×10^{-3}
10	12	-2.205×10^{-4}	2.225×10^{-6}	-7.614×10^{-12}	1.504×10^{-4}	3.815×10^{-12}	5.183×10^{-4}	-6.847×10^{-2}	-1.781×10^{-12}	-9.368×10^{0}	3.597×10^{-3}
11	13	8.830×10^{-5}	-6.788×10^{-8}	3.216×10^{-12}	7.759×10^{-5}	2.843×10^{-12}	7.294×10^{-5}	8.143×10^{-4}	2.921×10^{-12}	-1.004×10^{1}	4.152×10^{-3}
12	14	8.384×10^{-5}	1.080×10^{-7}	2.158×10^{-12}	9.921×10^{-5}	2.813×10^{-12}	1.088×10^{-4}	-1.466×10^{-3}	2.623×10^{-12}	-9.645×10^{0}	3.260×10^{-3}
13	15	-3.957×10^{-4}	3.056×10^{-6}	-1.061×10^{-11}	1.254×10^{-4}	4.104×10^{-12}	6.098×10^{-4}	-9.199×10^{-2}	-2.554×10^{-12}	-9.709×10^{0}	4.564×10^{-3}
14	16	-1.323×10^{-5}	9.594×10^{-7}	-2.370×10^{-12}	1.207×10^{-4}	3.609×10^{-12}	2.417×10^{-4}	-1.792×10^{-2}	1.107×10^{-12}	-9.564×10^{0}	3.754×10^{-3}
15	17	9.985×10^{-4}	-5.136×10^{-6}	2.927×10^{-11}	1.545×10^{-4}	3.222×10^{-12}	-6.621×10^{-4}	1.496×10^{-1}	1.521×10^{-11}	-9.220×10^{0}	2.945×10^{-3}
16	18	2.109×10^{-3}	-1.181×10^{-5}	6.280×10^{-11}	1.259×10^{-4}	4.537×10^{-12}	-1.727×10^{-3}	3.476×10^{-1}	3.068×10^{-11}	-9.624×10^{0}	4.373×10^{-3}
17	19	-1.390×10^{-4}	1.140×10^{-6}	-4.240×10^{-12}	3.816×10^{-5}	2.218×10^{-12}	2.071×10^{-4}	-2.909×10^{-2}	-7.619×10^{-13}	-1.106×10^{1}	6.159×10^{-3}
18	20	-5.892×10^{-5}	1.355×10^{-6}	-4.355×10^{-12}	1.319×10^{-4}	3.892×10^{-12}	3.111×10^{-4}	-2.726×10^{-2}	4.056×10^{-13}	-9.454×10^{0}	3.710×10^{-3}
19	21	7.061×10^{-5}	-1.080×10^{-7}	2.522×10^{-12}	5.563×10^{-5}	1.813×10^{-12}	3.988×10^{-5}	2.337×10^{-3}	2.173×10^{-12}	-1.017×10^{1}	3.089×10^{-3}
20	22	2.715×10^{-3}	-1.527×10^{-5}	7.409×10^{-11}	1.008×10^{-4}	4.120×10^{-13}	-2.363×10^{-3}	4.720×10^{-1}	3.408×10^{-11}	-9.355×10^{0}	8.462×10^{-4}
21	23	4.875×10^{-4}	-2.219×10^{-6}	1.735×10^{-10}	1.244×10^{-4}	6.109×10^{-12}	-2.183×10^{-4}	6.241×10^{-2}	1.113×10^{-11}	-9.691×10^{0}	5.118×10^{-3}
22	24	-5.017×10^{-5}	1.400×10^{-6}	-4.986×10^{-12}	1.389×10^{-4}	4.552×10^{-12}	3.147×10^{-4}	-2.529×10^{-2}	2.934×10^{-13}	-9.466×10^{0}	4.145×10^{-3}
23	25	6.430×10^{-5}	6.021×10^{-7}	2.317×10^{-12}	1.607×10^{-4}	5.550×10^{-12}	2.254×10^{-4}	-1.151×10^{-2}	4.507×10^{-12}	-9.330×10^{0}	4.143×10^{-3}
		$K = A + BT + CT^2$			$K = A + BT$						
24	26	5.498×10^{-6}	5.589×10^{-8}	-1.419×10^{-11}	6.427×10^{-6}	4.857×10^{-8}					
25	27	8.883×10^{-5}	8.920×10^{-8}	1.326×10^{-10}	7.978×10^{-5}	1.590×10^{-7}					
26	28	5.899×10^{-5}	3.155×10^{-7}	-2.648×10^{-10}	7.815×10^{-5}	1.724×10^{-7}					
27	29	6.611×10^{-5}	3.801×10^{-7}	-5.016×10^{-10}	1.061×10^{-4}	9.240×10^{-8}					

TABLE 3. FIGURE 1 DATA

Temperature (° K)	Thermal Conductivity (1×10^{-5} W/cm °K)
179	0.60
180	0.59
184	0.60
184	0.61
187	0.63
190	0.60
196	0.67
317	1.07
317	1.09
325	1.07
360	1.36
361	1.32
362	1.32
363	1.24
364	1.30
365	1.32



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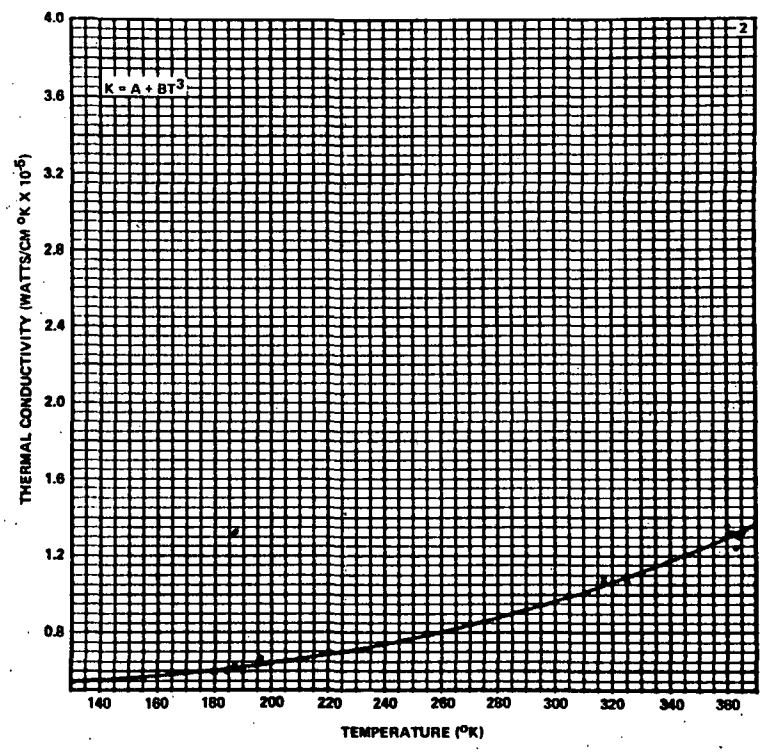


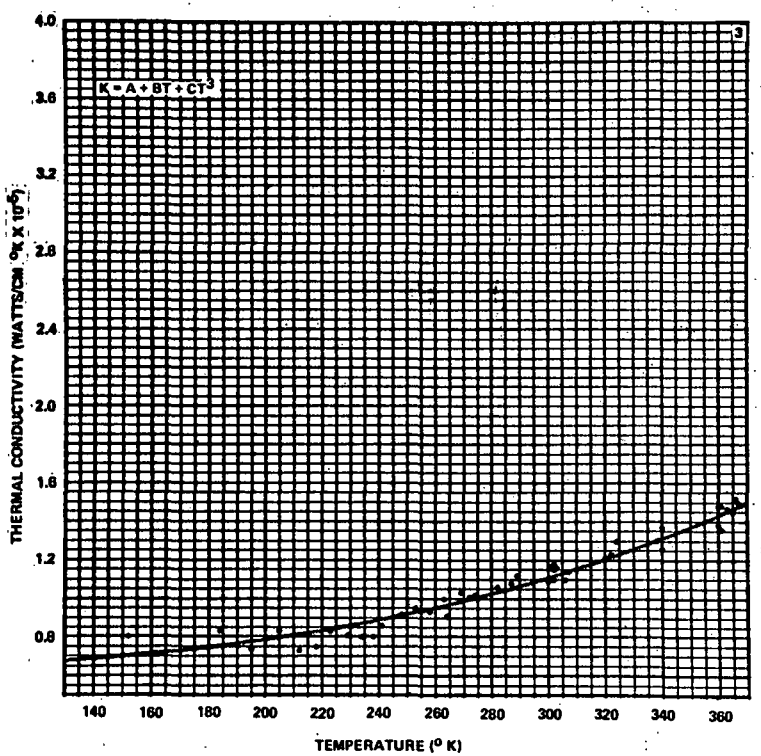
b.

SAMPLE: BASALT DENSITY: 0.79 g/cm^3 SAMPLE LOAD: 0
PARTICLE SIZE: 37-62 μm PRESSURE: 1.3×10^{-6} N/m^2

Figure 1. Thermal conductivity of basalt as a function of temperature (density — 0.79 g/cm^3).

TABLE 4. FIGURE 2 DATA

Temperature (° K)	Thermal Conductivity (1×10^{-5} W/cm °K)	Temperature (° K)	Thermal Conductivity (1×10^{-5} W/cm °K)
152.0	0.80	302.0	1.10
184.0	0.83	302.0	1.15
195.0	0.74	302.0	1.17
205.0	0.83	302.0	1.18
212.0	0.73	303.0	1.16
218.0	0.75	306.0	1.10
223.0	0.83	307.0	1.14
229.0	0.81	320.0	1.21
234.0	0.80	322.0	1.23
238.0	0.80	324.0	1.30
241.0	0.86	338.0	1.30
248.0	0.92	340.0	1.26
253.0	0.95	340.0	1.37
258.0	0.93	360.0	1.38
263.0	1.00	360.0	1.38
264.0	0.91	360.0	1.48
269.0	1.03	361.0	1.36
272.0	1.01	361.0	1.36
274.0	1.02	361.0	1.48
282.0	1.06	363.0	1.47
287.0	1.08	365.0	1.45
289.0	1.12	365.0	1.45
300.0	1.09	366.0	1.52
301.0	1.17	367.0	1.50



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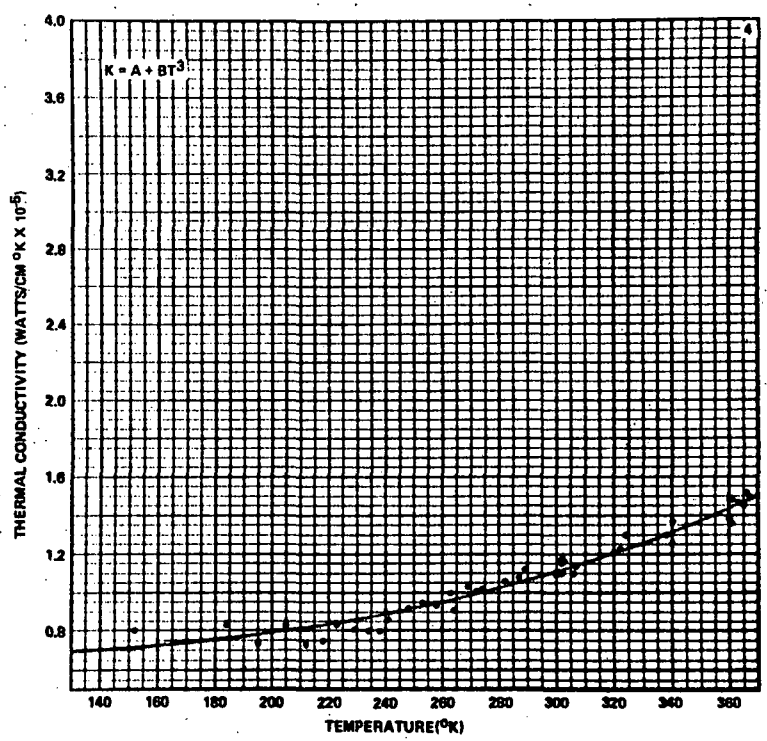


b.

SAMPLE: BASALT
PARTICLE SIZE: 37-62 μm

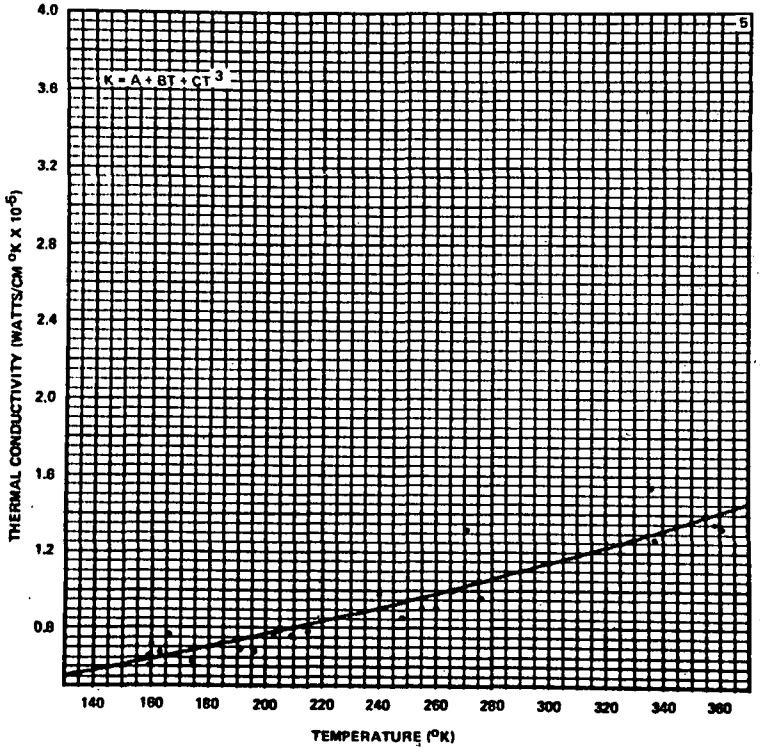
DENSITY: 0.88 g/cm^3
PRESSURE: 1.3×10^{-6} N/m^2

SAMPLE LOAD: 0

Figure 2. Thermal conductivity of basalt as a function of temperature (density — 0.88 g/cm^3).

TABLE 5. FIGURE 3 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)
159	0.61
159	0.66
160	0.72
163	0.68
166	0.77
174	0.63
184	0.72
191	0.69
196	0.68
203	0.76
209	0.76
215	0.78
240	0.98
248	0.86
255	0.91
260	0.91
266	1.00
271	1.32
276	0.96
336	1.54
337	1.27
337	1.27
358	1.35
361	1.33



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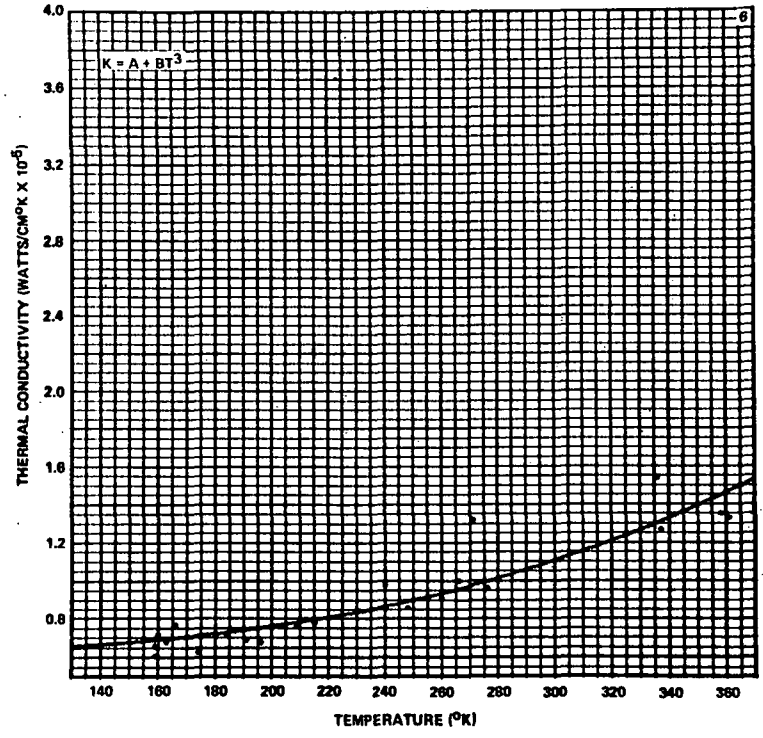


b.

SAMPLE: BASALT
PARTICLE SIZE: 37-62 μm

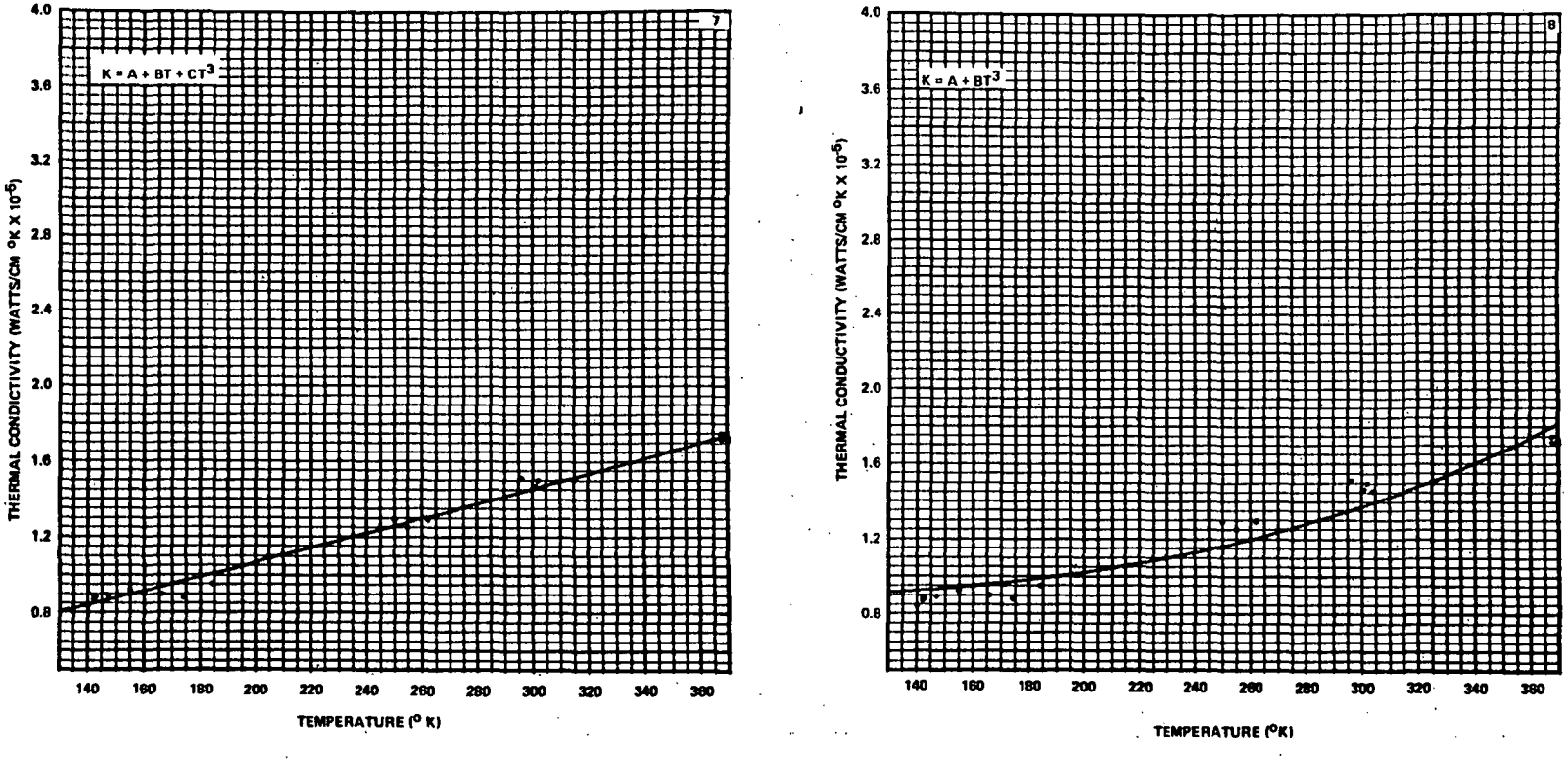
DENSITY: 0.98 g/cm^3
PRESSURE: 1.3×10^{-6} N/m^2

SAMPLE LOAD: 0

Figure 3. Thermal conductivity of basalt as a function of temperature (density — 0.98 g/cm^3).

TABLE 6. FIGURE 4 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)
140	0.84
142	0.87
142	0.89
143	0.88
147	0.89
155	0.92
166	0.90
174	0.88
184	0.95
250	1.29
255	1.25
262	1.29
262	1.30
296	1.51
301	1.47
302	1.50
304	1.46
368	1.72
368	1.75
370	1.71
370	1.73



a.

b.

SAMPLE: BASALT
PARTICLE SIZE: 37-62 μm

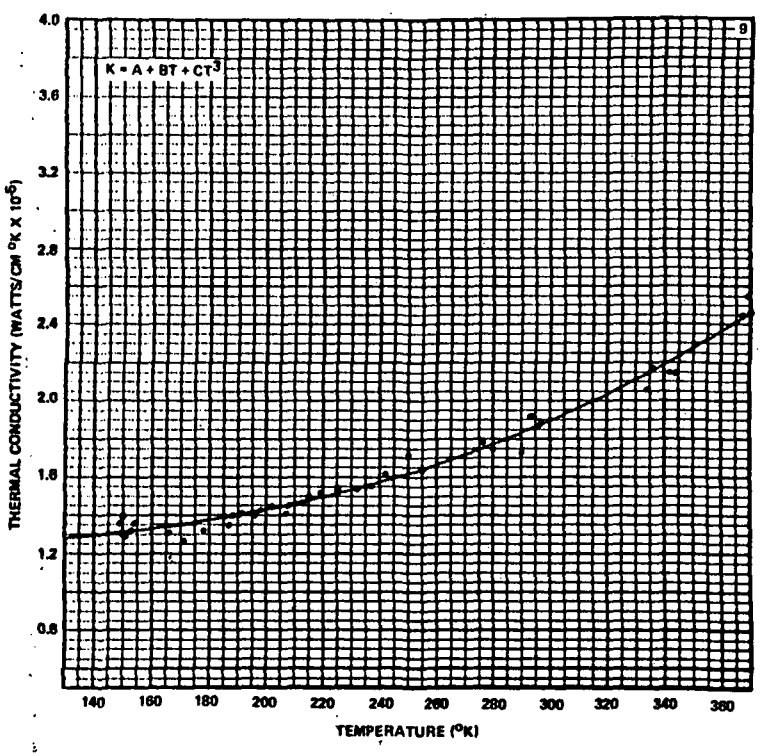
DENSITY: 1.13 g/cm^3
PRESSURE: 1.3×10^{-6} N/m^2

SAMPLE LOAD: 0

Figure 4. Thermal conductivity of basalt as a function of temperature (density — 1.13 g/cm^3).

TABLE 7. FIGURE 5 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)	Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)
149	1.36	225	1.54
150	1.30	232	1.54
150	1.39	237	1.56
151	1.29	242	1.62
153	1.32	250	1.72
154	1.36	255	1.64
166	1.31	276	1.78
171	1.27	280	1.75
178	1.32	290	1.73
187	1.35	293	1.92
188	1.40	294	1.92
191	1.41	296	1.87
196	1.40	297	1.89
198	1.43	334	2.06
202	1.45	336	2.17
207	1.41	342	2.15
208	1.45	344	2.15
213	1.47	367	2.45
215	1.50	369	2.55
219	1.52	370	2.46



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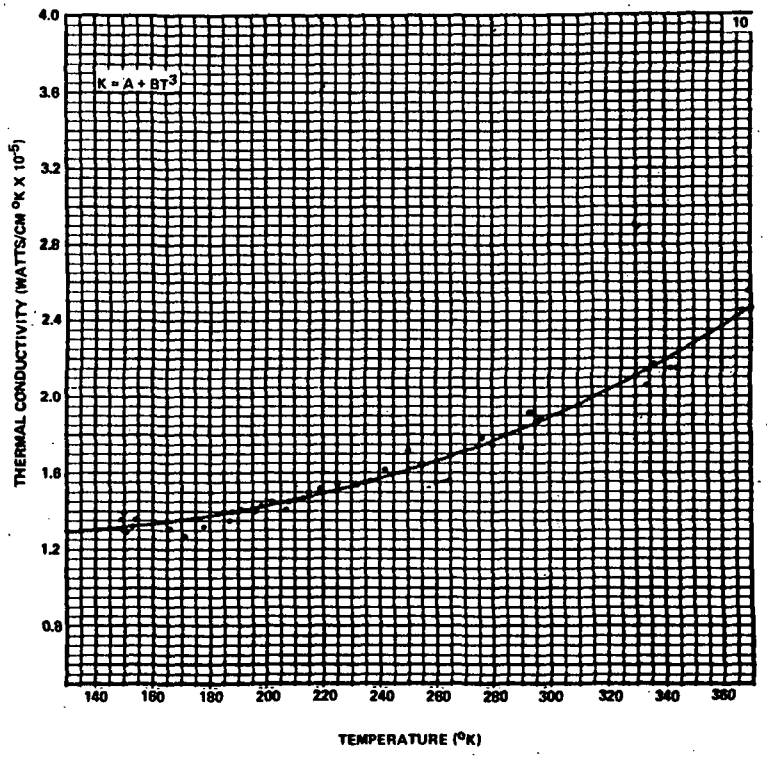


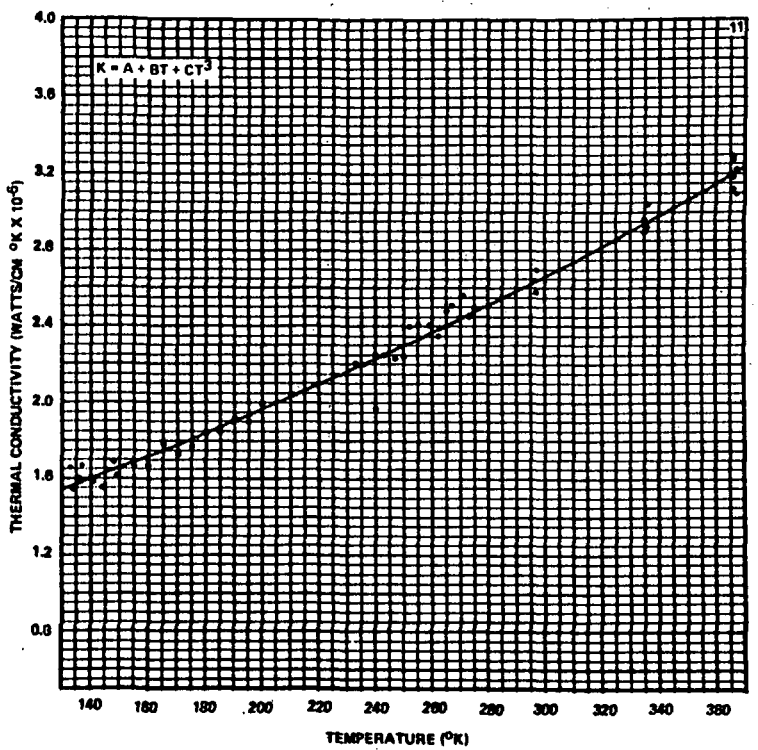
b.

SAMPLE: BASALT DENSITY: 1.30 g/cm^3 SAMPLE LOAD: 0
PARTICLE SIZE: 37-62 μm PRESSURE: 1.3 10^{-6} N/m^2

Figure 5. Thermal conductivity of basalt as a function of temperature (density — 1.30 g/cm^3).

TABLE 8. FIGURE 6 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)	Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)
133	1.66	247	2.23
134	1.54	250	2.24
136	1.58	252	2.40
136	1.60	255	2.41
136	1.60	259	2.41
137	1.67	262	2.35
141	1.58	265	2.48
144	1.55	267	2.51
148	1.69	271	2.56
149	1.62	273	2.45
155	1.67	275	2.49
160	1.67	297	2.58
165	1.78	297	2.58
170	1.73	297	2.70
175	1.77	335	2.89
180	1.84	335	2.96
185	1.85	336	2.92
190	1.92	336	3.04
195	1.90	366	3.12
200	1.99	366	3.18
233	2.21	366	3.27
236	2.20	366	3.29
240	1.97	367	3.09
240	2.25	367	3.22
243	2.25		



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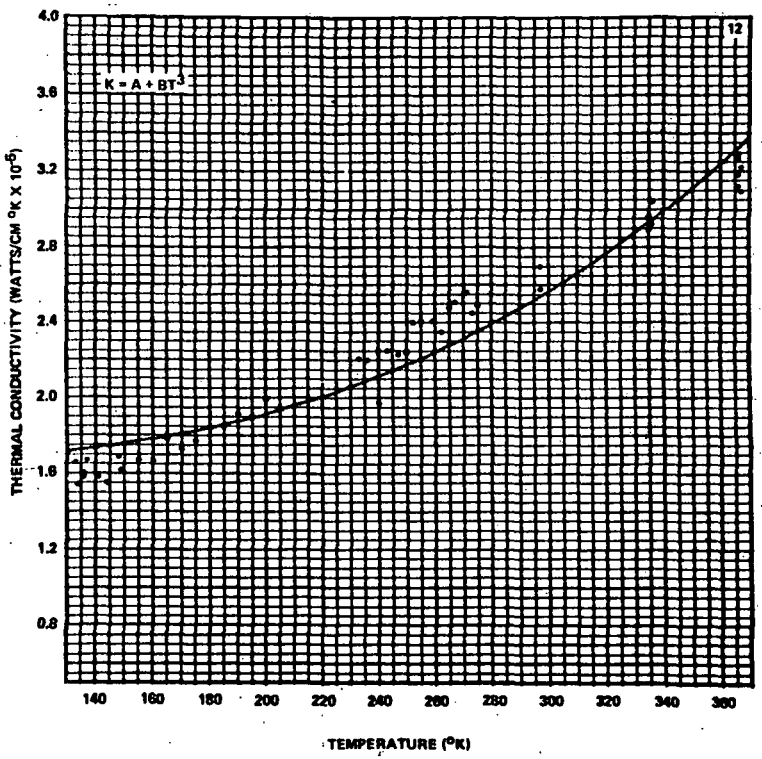


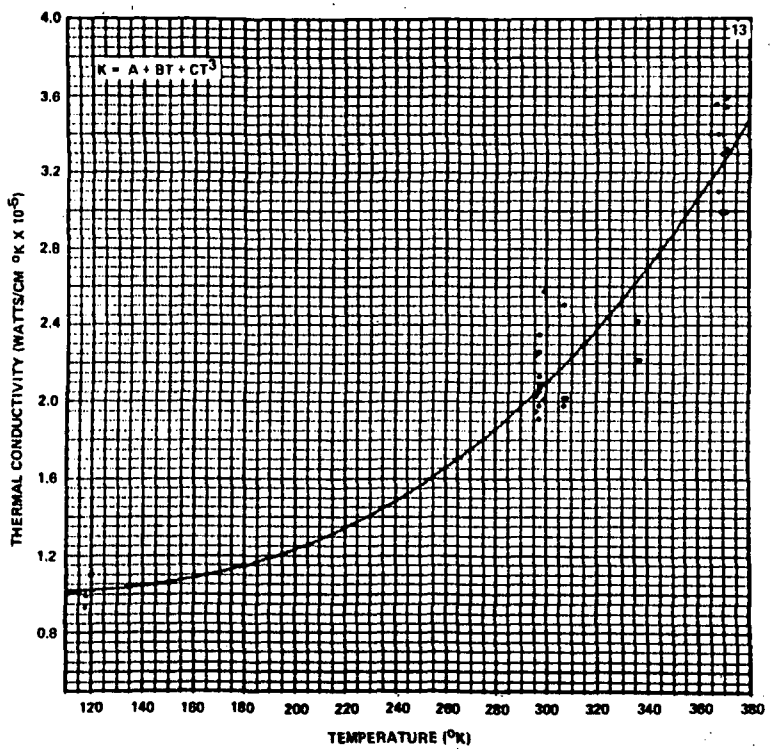
b.

SAMPLE: BASALT
PARTICLE SIZE: 37-62 μm
DENSITY: 1.50 g/cm^3
PRESSURE: 1.3×10^{-6} N/m^2
SAMPLE LOAD: 0

Figure 6. Thermal conductivity of basalt as a function of temperature (density — 1.50 g/cm^3)

TABLE 9. FIGURE 7 DATA

Temperature (°K)	Thermal Conductivity (10^{-5} W/cm °K)
118	0.93
118	0.99
120	1.10
296	1.95
296	2.03
296	2.25
297	1.91
297	1.98
297	2.05
297	2.07
297	2.09
297	2.13
297	2.26
297	2.35
298	2.09
299	2.01
299	2.58
307	1.98
307	2.02
307	2.51
308	2.02
336	2.22
336	2.42
337	2.22
367	3.56
368	3.10
368	3.40
369	2.99
369	3.30
371	2.99
371	3.32
371	3.54
371	3.59



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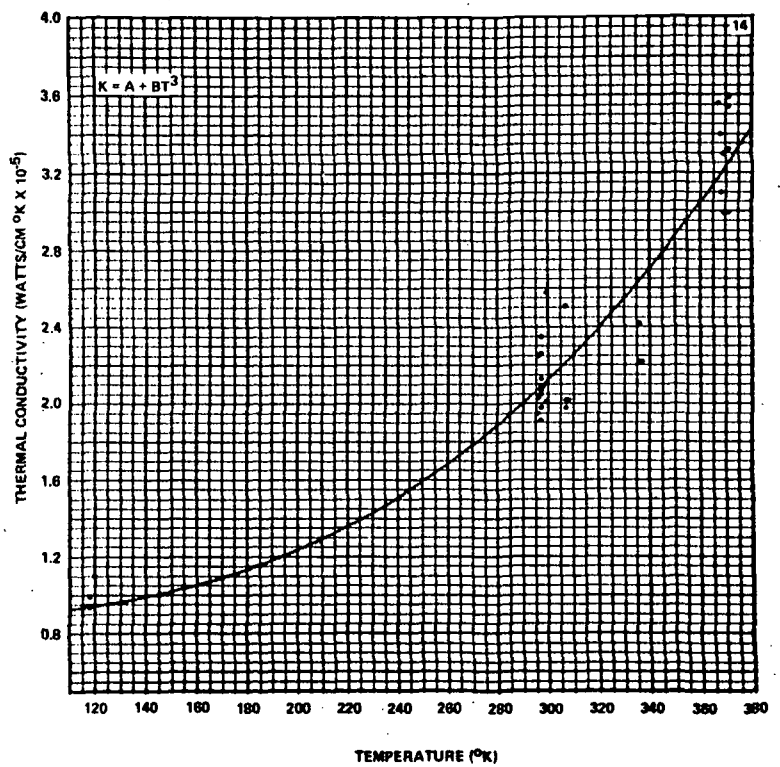

b.

SAMPLE: GLASS BEADS
PARTICLE SIZE: 30-38 μm

DENSITY: 1.58 g/cm^3
PRESSURE: 1.3×10^{-6} N/m^2

SAMPLE LOAD: 0

Figure 7. Thermal conductivity of glass beads as a function of temperature (particle size — 30 to 38 μm; measured by conventional line heat source method).

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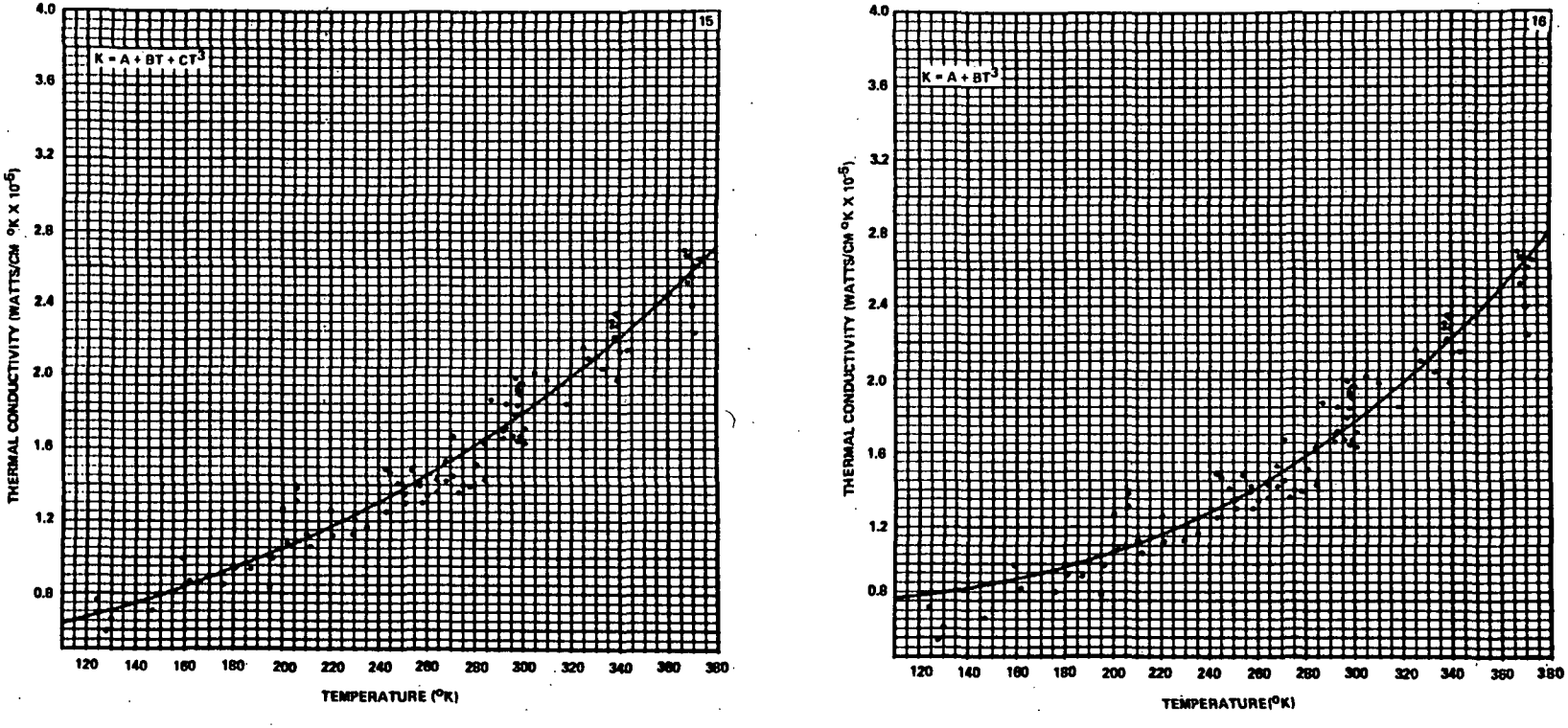
TABLE 10. FIGURE 8 DATA

Temperature (°K)	Thermal Conductivity (10^{-5} W/cm °K)	Temperature (°K)	Thermal Conductivity (10^{-5} W/cm °K)
122	0.72	243	1.25
124	0.77	243	1.49
128	0.59	245	1.47
130	0.66	248	1.41
147	0.71	251	1.30
159	0.99	251	1.35
162	0.87	254	1.48
176	0.85	257	1.39
181	0.94	257	1.42
187	0.93	258	1.30
195	0.83	260	1.34
196	0.99	264	1.36
200	1.27	264	1.43
202	1.08	268	1.42
206	1.38	268	1.53
206	1.31	271	1.67
210	1.13	271	1.45
212	1.06	273	1.36
220	1.26	275	1.40
221	1.12	278	1.39
229	1.13	281	1.51
230	1.21	284	1.43
235	1.17	284	1.63

TABLE 10. FIGURE 8 DATA (Concluded)

Temperature (°K)	Thermal Conductivity (10^{-5} W/cm °K)	Temperature (°K)	Thermal Conductivity (10^{-5} W/cm °K)
287	1.87	325	2.16
292	1.66	327	2.10
292	1.70	333	2.04
293	1.72	337	2.28
293	1.85	337	2.31
296	1.67	338	2.22
297	1.79	338	2.35
297	1.99	339	2.35
298	1.92	339	2.34
298	1.93	339	2.28
298	1.84	339	1.98
298	1.64	340	2.14
299	1.91	343	2.15
299	1.90	367	2.70
299	1.67	368	2.67
299	1.96	368	2.52
300	1.96	369	2.67
300	1.80	370	2.39
301	1.71	370	2.55
301	1.63	371	2.61
305	2.02	371	2.24
310	1.98	373	2.65
318	1.85		



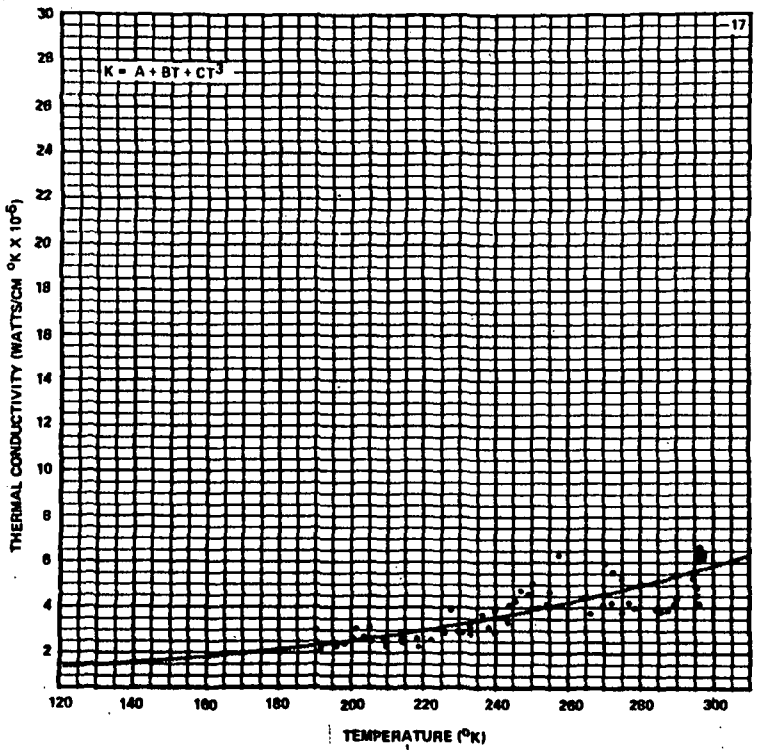
a. b.

SAMPLE: GLASS BEADS DENSITY: 1.58 g/cm^3 SAMPLE LOAD: 0
PARTICLE SIZE: 30-38 μm PRESSURE: 1.3×10^{-6} N/m^2

Figure 8. Thermal conductivity of glass beads as a function of temperature (particle size — 30 to 38 μm).

TABLE 11. FIGURE 9 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)	Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)
190.5	2.99	257.5	6.31
191.3	2.18	266.4	3.75
196.0	2.33	269.8	4.13
198.1	2.42	270.3	5.99
200.2	2.70	272.2	4.22
201.4	3.11	272.4	5.59
203.6	2.73	274.8	5.30
205.1	3.18	275.0	3.78
205.5	2.53	276.8	4.22
209.1	2.56	278.5	3.96
209.4	2.30	284.3	3.90
213.9	2.64	285.9	3.85
214.0	2.46	287.6	3.88
218.2	2.66	289.2	4.15
218.5	2.29	290.1	4.40
222.0	2.60	294.6	5.33
226.1	2.88	295.5	4.90
227.9	3.90	295.6	4.53
229.6	2.96	295.6	4.16
231.0	2.91	295.7	6.48
233.1	3.17	296.0	6.06
233.2	2.84	296.0	6.18
236.5	3.70	296.0	6.37
238.2	3.15	296.1	6.47
240.1	2.91	296.1	6.62
240.1	3.88	296.2	4.20
243.5	3.37	296.2	6.11
243.8	4.13	296.4	6.43
245.6	4.29	296.4	6.49
246.9	4.76	296.6	6.17
248.8	4.59	296.6	6.68
250.2	5.06	296.9	6.20
251.9	3.96	297.3	6.13
254.2	4.16	297.5	6.27
254.7	4.69	297.5	6.38



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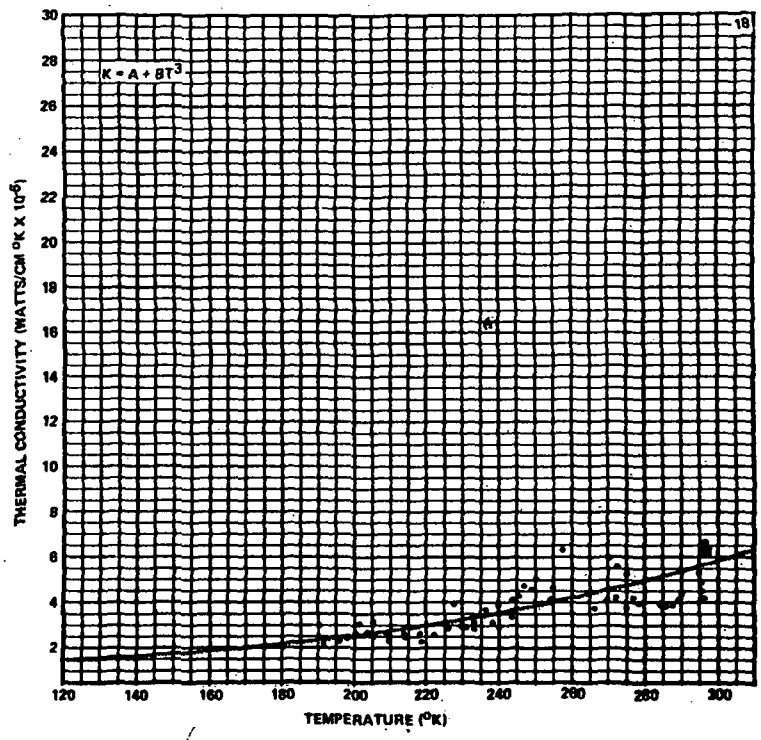


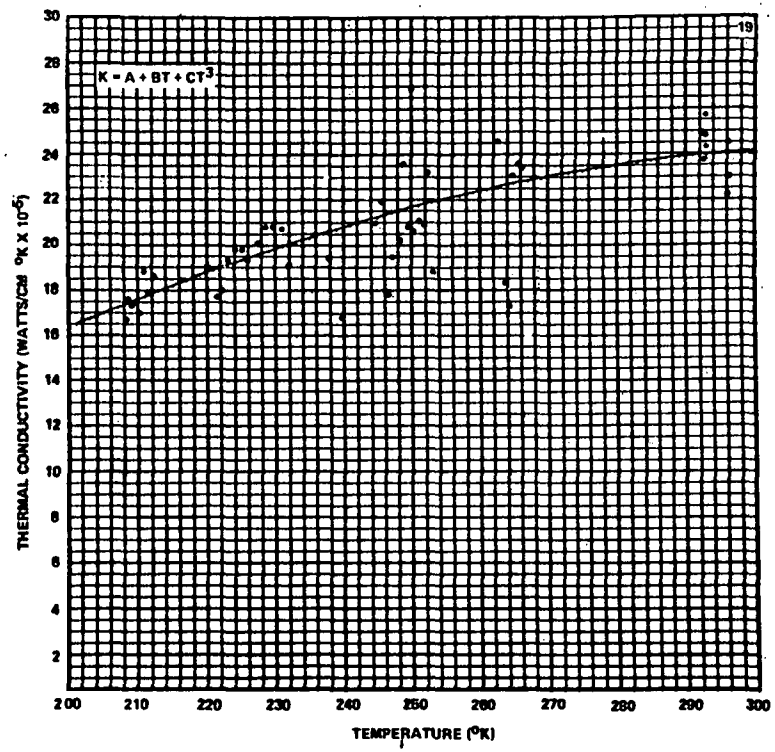
b.

SAMPLE: GLASS BEADS DENSITY: 1.50 g/cm^3 SAMPLE LOAD: 0
PARTICLE SIZE: 590-840 μm PRESSURE: 1.3×10^{-6} N/m^2

Figure 9. Thermal conductivity of glass beads as a fucntion of temperature (sample load — 0; pressure — 1.3×10^{-6} N/m^2).

TABLE 12. FIGURE 10 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)	Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
208.3	1.67	247.1	1.95
208.6	1.76	248.3	2.02
209.1	1.73	248.8	2.36
209.6	1.75	249.4	2.08
210.3	1.70	250.0	2.69
211.0	1.88	250.3	2.06
211.7	1.79	251.1	2.11
212.4	1.86	251.1	3.44
220.3	1.90	251.8	2.09
221.4	1.77	252.4	2.32
222.3	1.80	253.2	1.88
223.1	1.93	262.6	2.46
224.1	1.98	263.6	1.83
225.2	1.98	264.3	1.73
225.9	1.93	264.9	2.31
227.5	2.01	265.6	2.36
228.6	2.08	266.2	2.34
229.6	2.08	292.3	2.49
231.0	2.07	292.6	2.37
232.0	1.91	292.8	2.48
237.8	1.94	292.9	2.57
239.7	1.68	293.0	2.43
244.7	2.10	296.1	2.22
245.6	2.19	296.2	2.45
246.5	1.78	296.4	2.30



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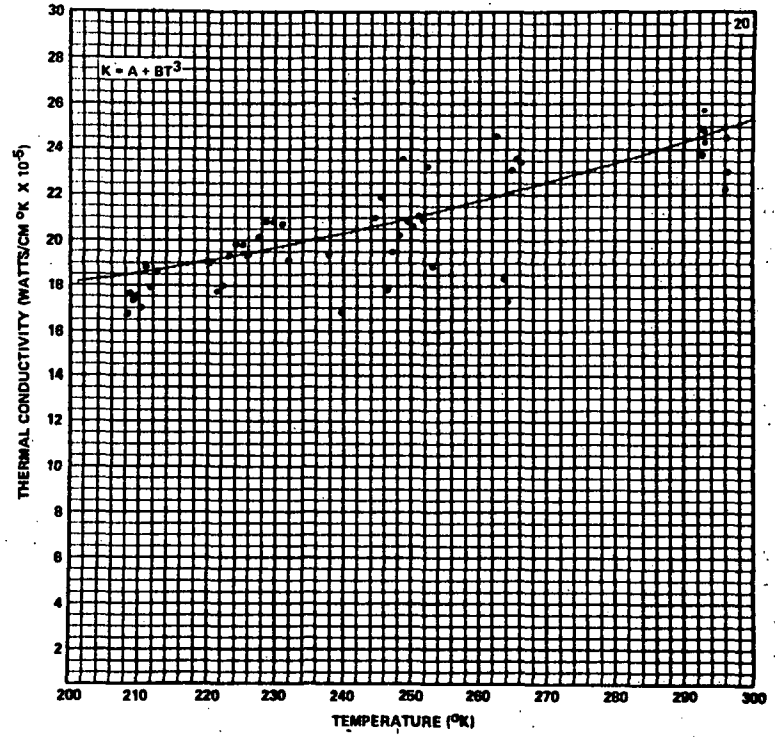


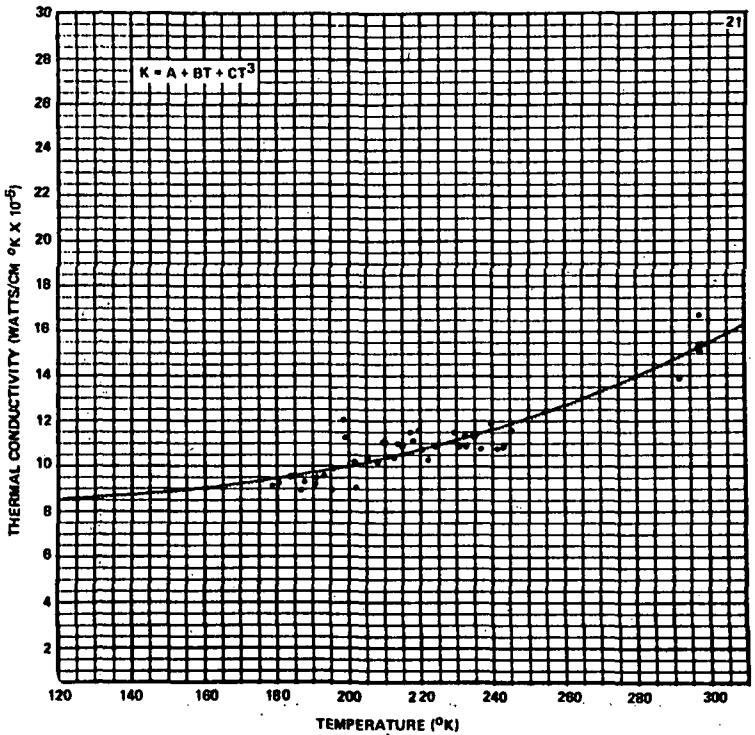
b.

SAMPLE: GLASS BEADS
PARTICLE SIZE: 590-840 μm
DENSITY: 1.50 g/cm^3
PRESSURE: 1.3×10^{-6} N/m^2
SAMPLE LOAD: 150 g/cm^2

Figure 10. Thermal conductivity of glass beads as a function of temperature (sample load — 150 g/cm^2; density — 1.50 g/cm^3; pressure — 1.3 10^{-6} N/m^2).

TABLE 13. FIGURE 11 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)	Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
178.7	0.92	217.9	1.12
180.6	0.93	219.6	1.16
183.9	0.96	220.6	1.08
186.7	0.90	222.1	1.03
187.6	0.93	224.2	1.09
190.6	0.92	229.3	1.15
191.0	0.95	230.8	1.09
193.1	0.96	232.3	1.14
195.4	0.90	232.7	1.09
196.0	0.99	234.9	1.14
198.6	1.21	235.1	1.13
199.1	1.13	236.9	1.08
201.6	1.02	239.7	1.19
202.0	0.91	241.3	1.08
205.1	1.04	243.2	1.09
208.1	1.02	245.4	1.16
209.5	1.11	292.0	1.39
210.3	1.10	297.2	1.52
212.7	1.04	297.4	1.53
213.6	1.10	297.6	1.67
215.0	1.09	297.7	1.51
217.2	1.15	297.7	1.54



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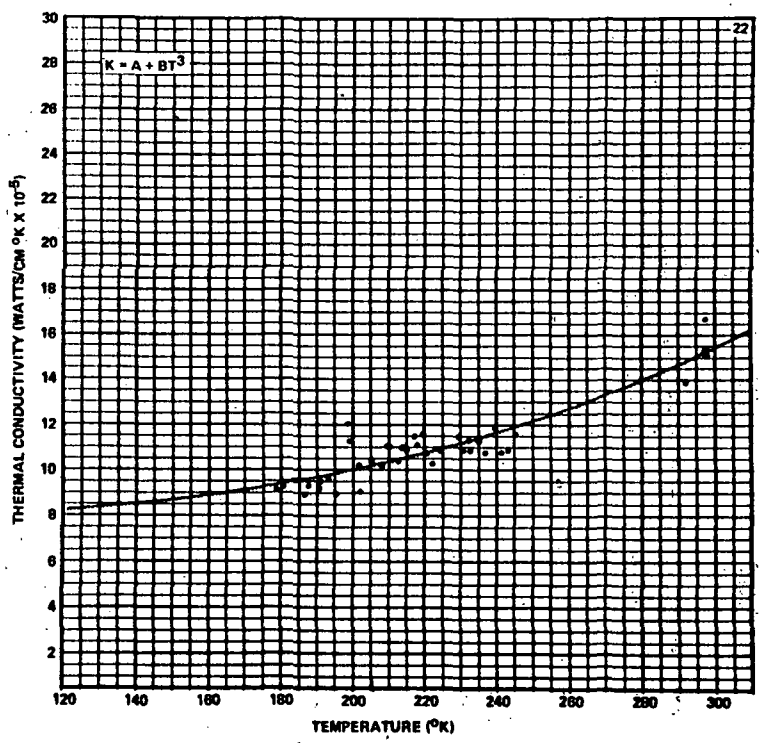


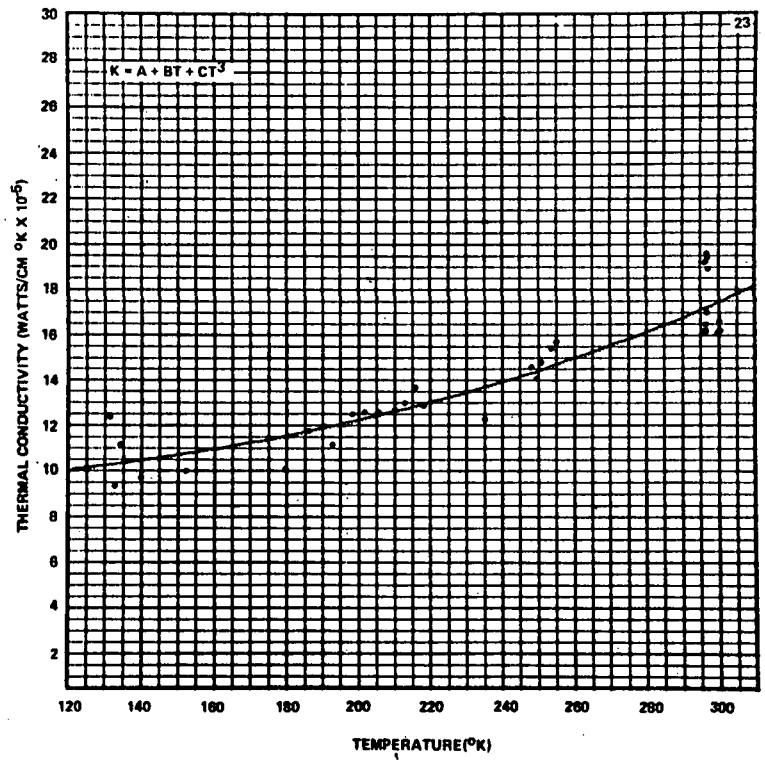
b.

SAMPLE: GLASS BEADS DENSITY: 1.58 g/cm^3 SAMPLE LOAD: 198 g/cm^2
PARTICLE SIZE: 590-840 μm PRESSURE: 1.3×10^{-6} N/m^2

Figure 11. Thermal conductivity of glass beads as a function of temperature (sample load — 198 g/cm^2).

TABLE 14. FIGURE 12 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
131.3	1.24
132.8	0.94
134.0	1.12
139.7	0.97
152.1	1.00
179.5	1.01
186.1	1.18
192.8	1.12
198.3	1.25
201.6	1.26
205.5	1.26
210.0	1.27
212.8	1.30
215.8	1.37
218.2	1.29
235.1	1.23
248.0	1.46
249.5	1.41
250.8	1.48
253.6	1.54
255.0	1.57
295.9	1.62
296.4	1.62
296.4	1.65
296.4	1.92
296.6	1.65
296.7	1.70
296.8	1.70
296.8	1.96
297.0	1.94
297.1	1.89
297.7	1.61
300.1	1.66
300.3	1.62
300.4	1.62



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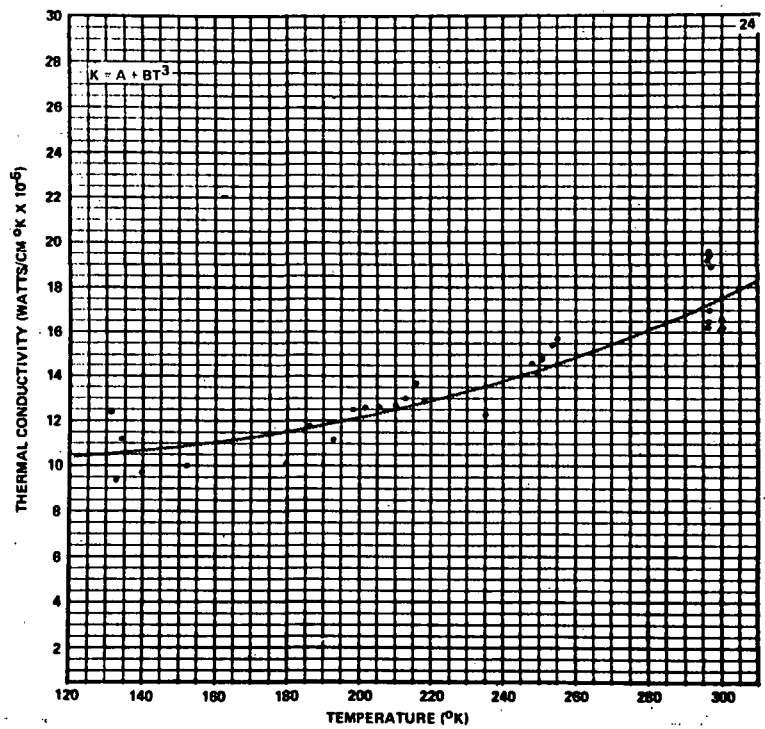


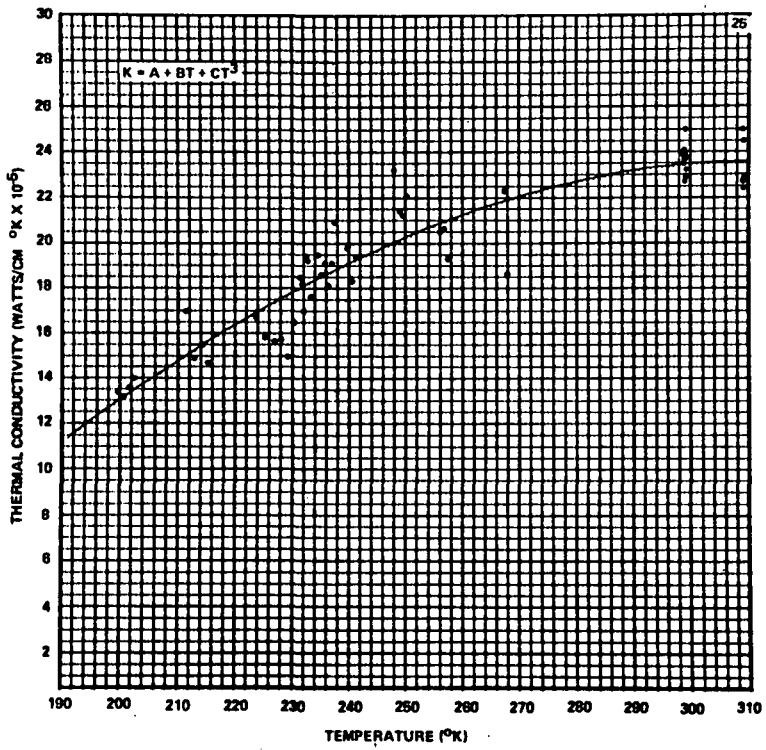
b.

SAMPLE: GLASS BEADS
PARTICLE SIZE: 590-840 μm
DENSITY: 1.58 g/cm^3
PRESSURE: 1.3×10^{-6} N/m^2
SAMPLE LOAD: 348 g/cm^2

Figure 12. Thermal conductivity of glass beads as a function of temperature (sample load — 348 g/cm^2; pressure — 1.3×10^{-6} N/m^2).

TABLE 15. FIGURE 13 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)	Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
199.5	1.34	240.6	1.83
200.6	1.32	241.2	1.94
201.6	1.36	247.9	2.32
202.6	1.40	248.9	2.14
211.4	1.70	249.5	2.12
212.9	1.49	250.2	2.21
214.2	1.55	256.1	2.05
215.3	1.47	256.8	2.06
223.7	1.67	257.4	1.93
225.2	1.58	267.4	2.23
226.9	1.56	267.9	1.86
228.1	1.57	298.6	2.39
229.2	1.50	298.7	2.35
230.3	1.65	298.8	2.41
231.3	1.85	299.0	2.27
231.8	1.82	299.0	2.39
232.1	1.70	299.1	2.50
232.4	1.94	299.2	2.29
232.8	1.92	299.2	2.32
233.3	1.76	299.2	2.37
234.6	1.95	299.2	2.38
235.2	1.86	309.0	2.50
235.8	1.91	309.1	2.24
236.4	1.81	309.1	2.27
237.0	1.91	309.1	2.27
237.5	2.09	309.1	2.28
239.8	1.98	309.1	2.45



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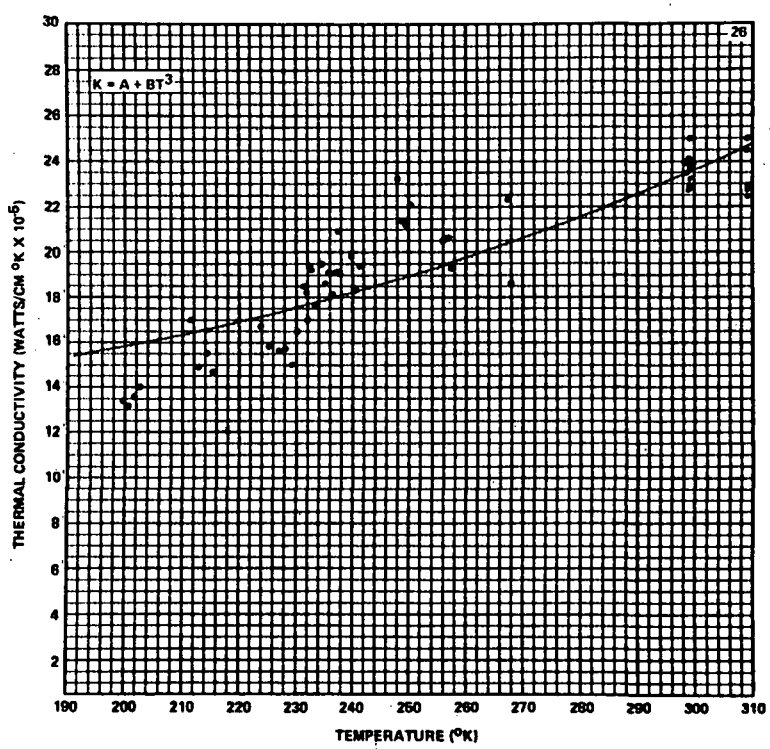


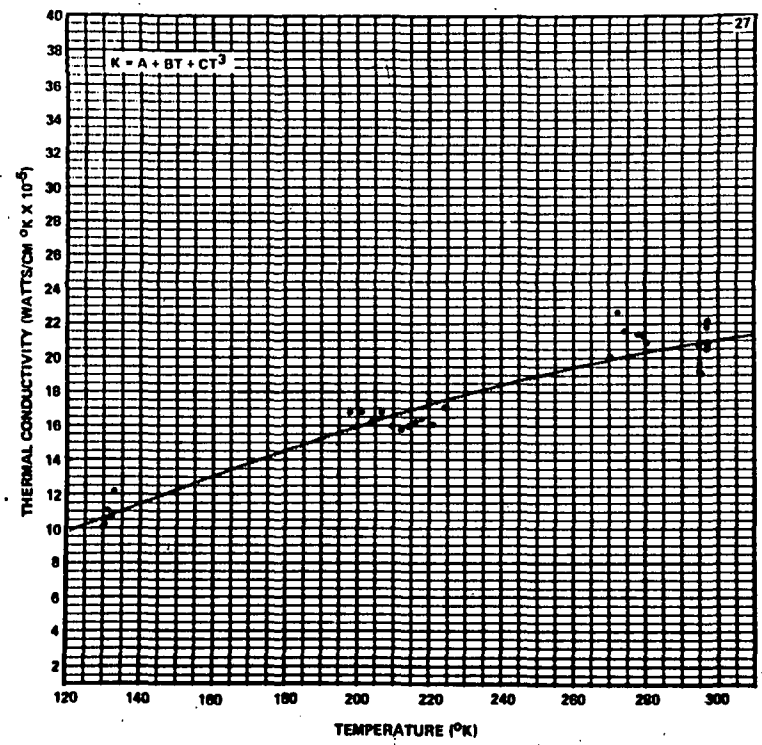
b.

SAMPLE: GLASS BEADS DENSITY: 1.58 g/cm^3 SAMPLE LOAD: 150 g/cm^2
PARTICLE SIZE: 590-840 μm PRESSURE: 1.3×10^{-2} N/m^2

Figure 13. Thermal conductivity of glass beads as a function of temperature (pressure — 1.3×10^{-2} N/m^2; sample load — 150 g/cm^2).

TABLE 16. FIGURE 14 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
129.9	1.01
130.3	1.02
131.2	1.11
132.1	1.06
132.9	1.22
198.0	1.68
201.2	1.68
204.1	1.63
206.7	1.68
209.7	1.60
212.2	1.58
214.2	1.60
215.9	1.62
217.9	1.64
220.0	1.75
221.1	1.61
224.2	1.71
270.4	2.01
272.3	2.27
274.1	2.16
277.9	2.14
279.2	2.13
280.4	2.09
294.8	2.07
295.0	1.97
295.0	1.92
295.3	1.91
296.9	2.18
297.0	2.05
297.1	2.07
297.1	2.08
297.1	2.09
297.1	2.09
297.1	2.22
297.2	2.05
297.2	2.09



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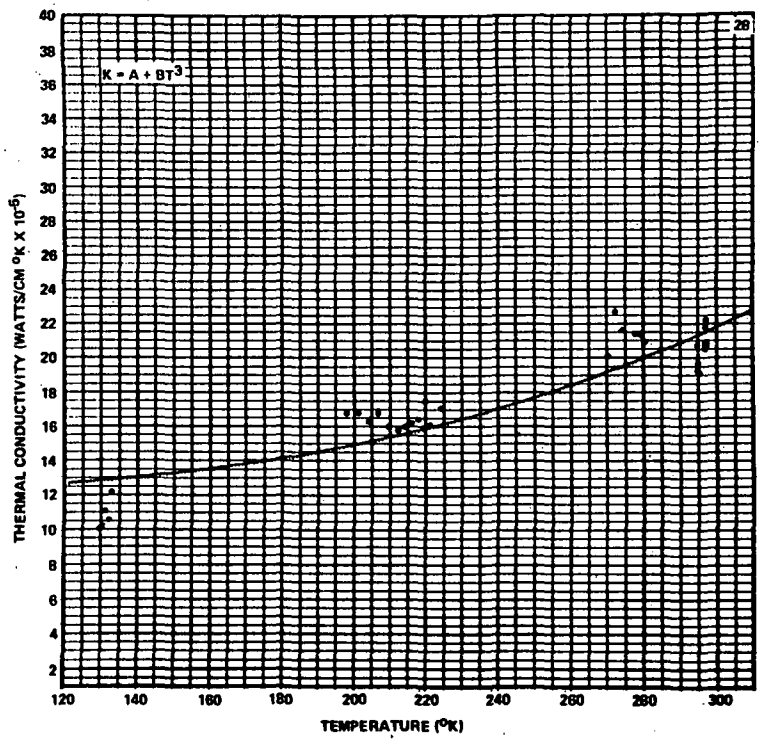


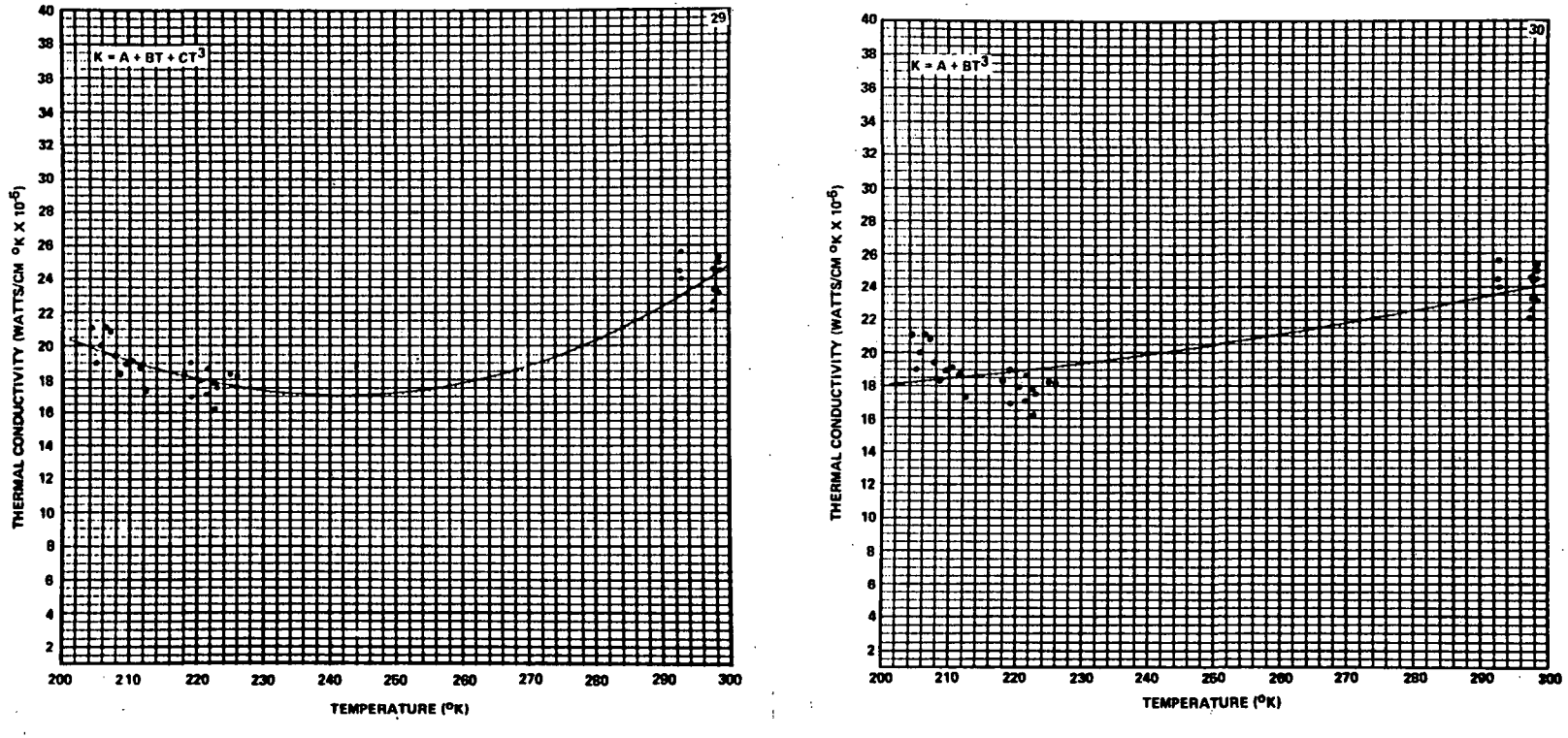
b.

SAMPLE: GLASS BEADS DENSITY: 1.58 g/cm^3 SAMPLE LOAD: 348 g/cm^2
PARTICLE SIZE: 590-840 μm PRESSURE: 1.3×10^{-1} N/m^2 (N_2)

Figure 14. Thermal conductivity of glass beads as a function of temperature [pressure — 1.3×10^{-1} N/m^2 (N_2); sample load — 348 g/cm^2].

TABLE 17. FIGURE 15 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
204.4	2.11
205.1	1.90
205.6	2.00
206.4	2.11
207.1	2.08
207.8	1.94
208.6	1.83
209.4	1.89
210.4	1.91
211.5	1.87
212.4	1.73
218.0	1.83
219.1	1.90
219.2	1.69
220.4	1.79
220.5	1.79
221.3	1.71
221.6	1.86
222.5	1.78
222.7	1.62
223.0	1.75
225.0	1.83
226.0	1.82
292.7	2.45
292.9	2.56
293.0	2.40
297.4	2.21
297.6	2.46
297.7	2.26
297.8	2.33
298.0	2.33
298.0	2.45
298.5	2.31
298.5	2.50
298.6	2.45
298.6	2.53



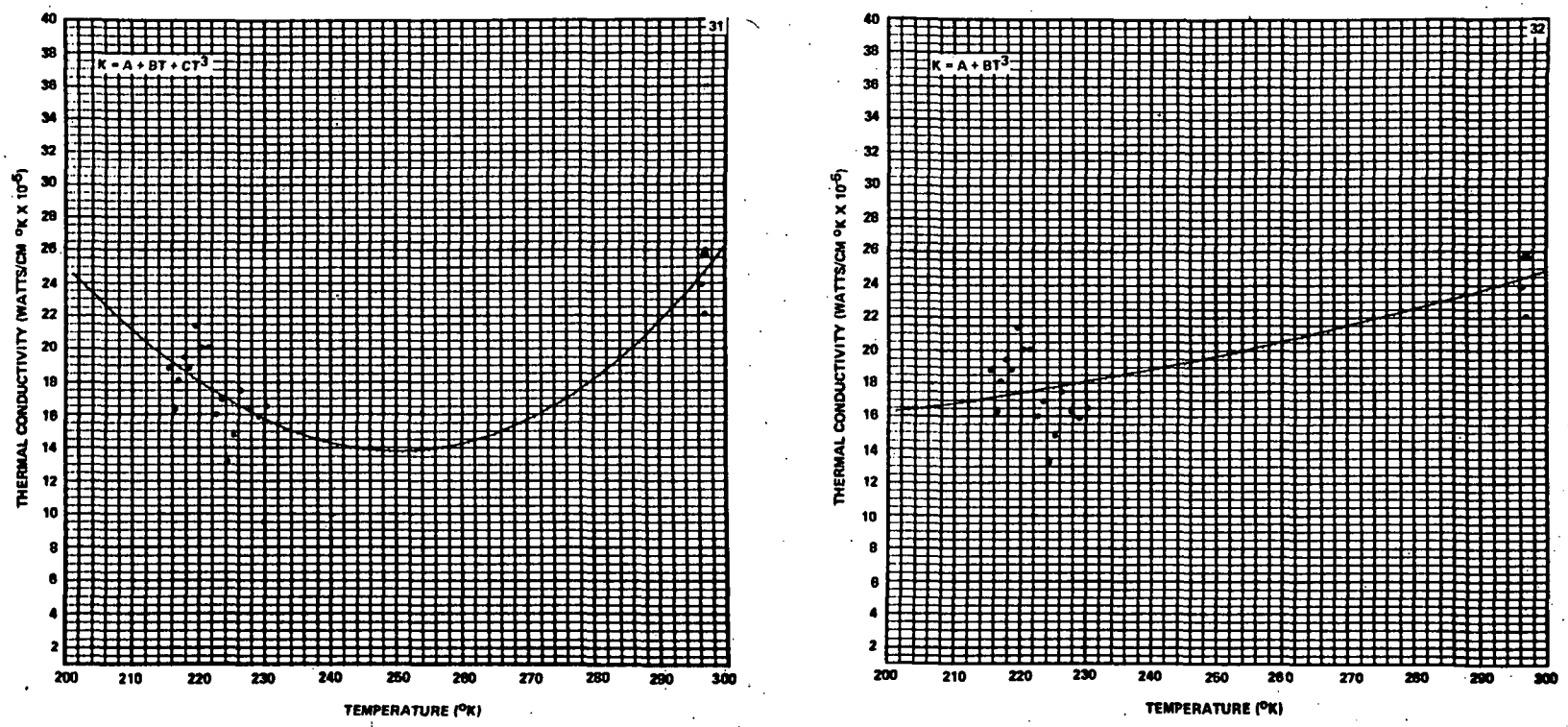
a. b.

SAMPLE: GLASS BEADS PRESSURE: 1.3×10^{-1} N/m^2 (N_2) SAMPLE LOAD: 150 g/cm^2
PARTICLE SIZE: 590-840 μm DENSITY: 1.58 g/cm^3

Figure 15. Thermal conductivity of glass beads as a function of temperature [pressure — 1.3×10^{-1} N/m^2 (N_2); sample load — 150 g/cm^2].

TABLE 18. FIGURE 16 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
215.4	1.88
216.4	1.63
216.9	1.81
217.7	1.95
218.5	1.88
219.5	2.14
220.4	2.01
221.3	2.01
222.6	1.60
223.4	1.69
224.4	1.32
225.3	1.48
226.3	1.75
227.7	1.63
229.0	1.59
230.3	1.65
296.5	2.39
296.7	2.57
296.9	2.21
297.0	2.59
297.1	2.57



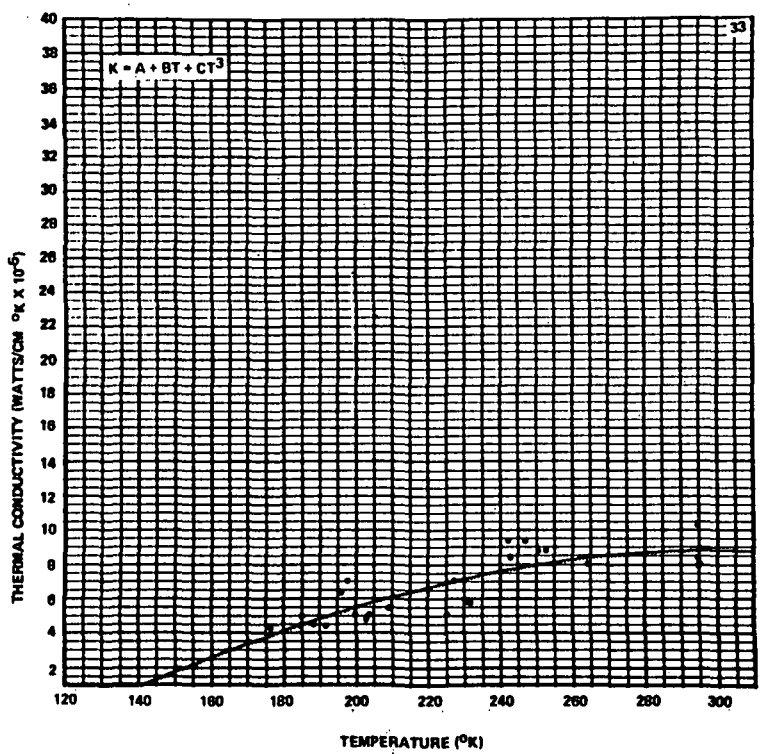
a. b.

SAMPLE: GLASS BEADS DENSITY: 1.58 g/cm^3 SAMPLE LOAD: 150 g/cm^2
PARTICLE SIZE: 590-840 μm PRESSURE: 1.3 N/m^2 (N_2)

Figure 16. Thermal conductivity of glass beads as a function of temperature [pressure — 1.3 N/m^2 (N_2); sample load — 150 g/cm^2].

TABLE 19. FIGURE 17 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)
176.5	4.30
184.7	4.44
185.0	5.02
188.4	4.50
191.7	4.41
196.0	6.32
197.7	7.03
199.8	5.07
202.7	4.80
203.5	5.08
209.1	5.47
225.2	5.08
227.2	7.05
230.8	5.81
231.7	5.75
242.2	9.39
243.0	8.40
247.0	9.33
250.5	8.78
252.7	8.79
264.3	8.01
294.5	10.30
294.7	8.38
294.9	7.95
295.2	8.09



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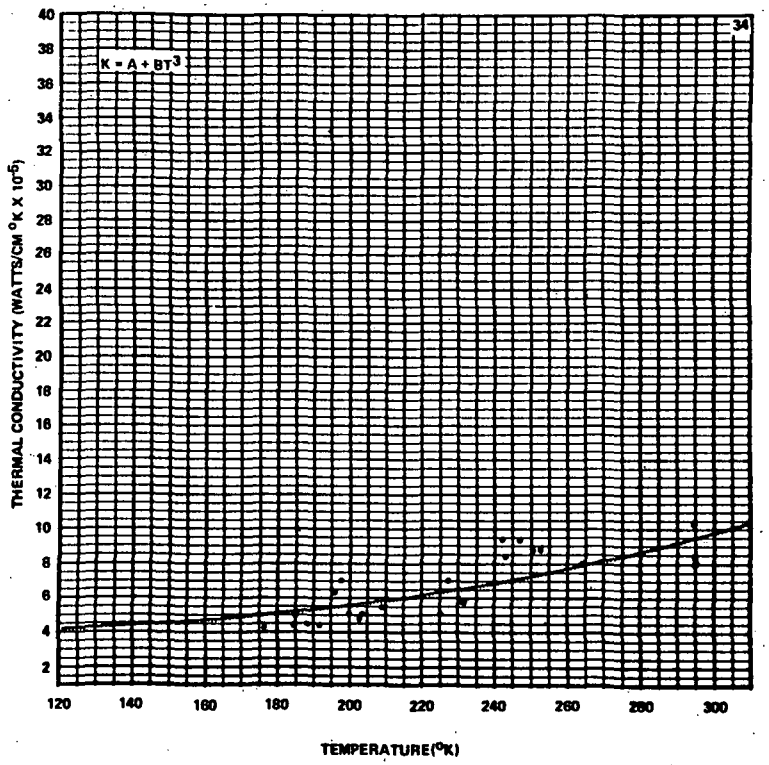


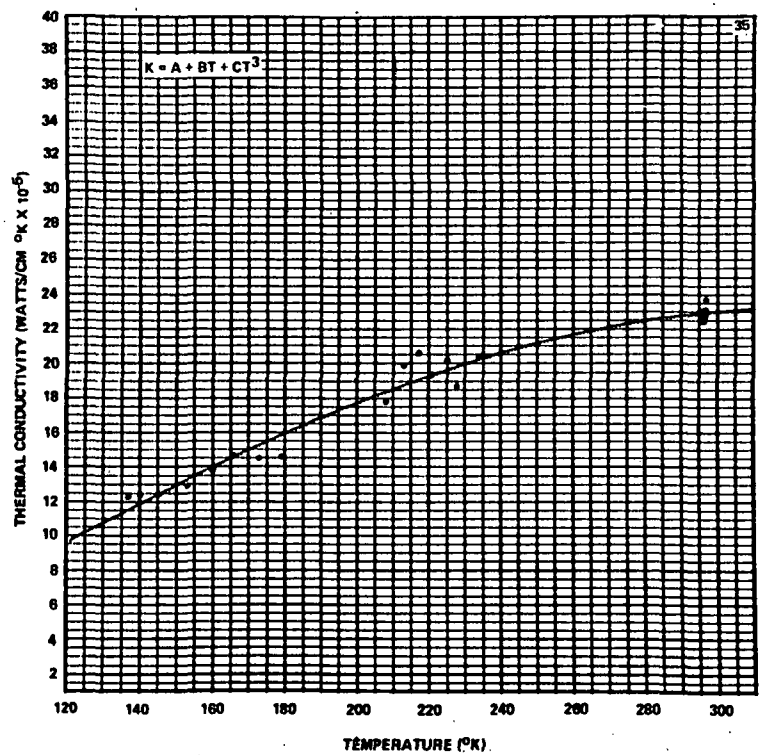
b.

SAMPLE: GLASS BEADS
PARTICLE SIZE: 590-840 μm
DENSITY: 1.51 g/cm^3
PRESSURE: 3.25 N/m^2 (N_2)
SAMPLE LOAD: 0

Figure 17. Thermal conductivity of glass beads as a function of temperature (density — 1.51 g/cm^3; sample load — 0).

TABLE 20. FIGURE 18 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
136.9	1.23
140.2	1.24
145.1	1.24
153.2	1.29
160.1	1.38
165.7	1.47
172.9	1.45
178.9	1.46
208.1	1.78
213.1	1.99
217.2	2.06
220.5	1.93
225.0	2.02
227.9	1.87
233.9	2.04
295.7	2.29
295.8	2.27
295.9	2.30
296.3	2.24
296.5	2.27
296.6	2.27
296.6	2.30
296.7	2.29
296.7	2.30
296.7	2.31
296.8	2.30
296.9	2.37



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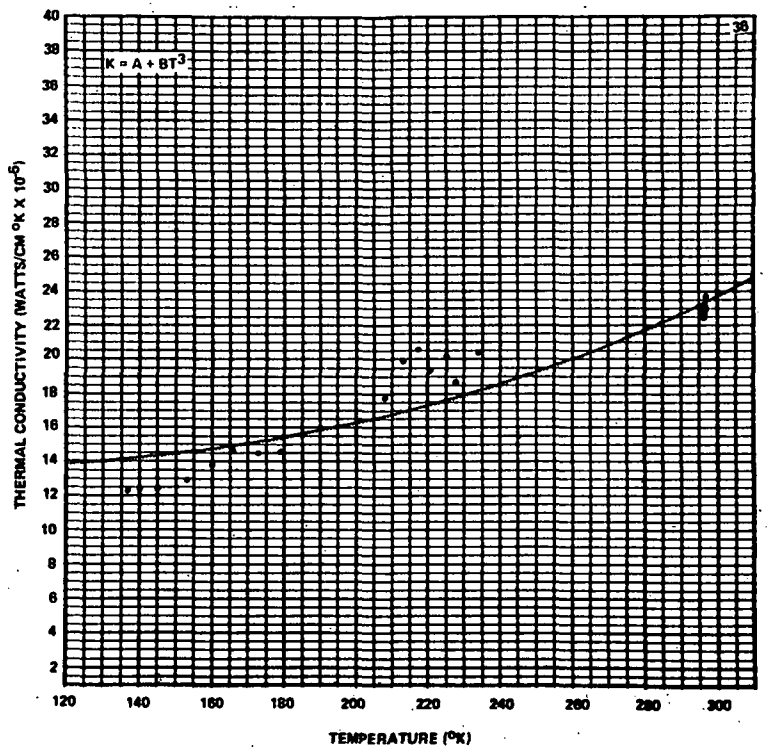


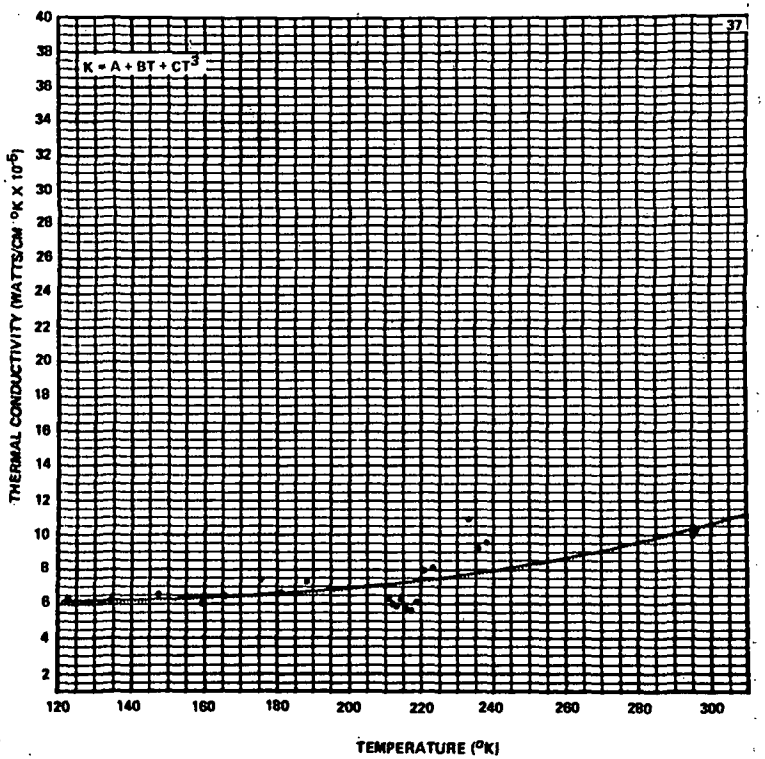
b.

SAMPLE: GLASS BEADS
PARTICLE SIZE: 590-840 μm
DENSITY: 1.58 g/cm^3
PRESSURE: 3.25 N/m^2 (N_2)
SAMPLE LOAD: 348 g/cm^2

Figure 18. Thermal conductivity of glass beads as a function of temperature (density — 1.58 g/cm^3; sample load — 348 g/cm^2).

TABLE 21. FIGURE 19 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-5} W/cm °K)
122.9	6.32
128.4	6.17
134.2	6.26
147.5	6.56
159.3	6.07
165.5	6.51
175.5	7.41
181.1	6.69
188.3	7.29
211.0	6.36
212.1	6.03
213.2	5.87
214.4	6.29
215.7	5.76
217.2	5.65
218.7	6.17
220.7	7.97
223.2	8.14
233.1	10.90
235.8	9.26
238.3	9.61
295.1	9.97
295.2	10.20
295.4	10.20
295.8	10.30



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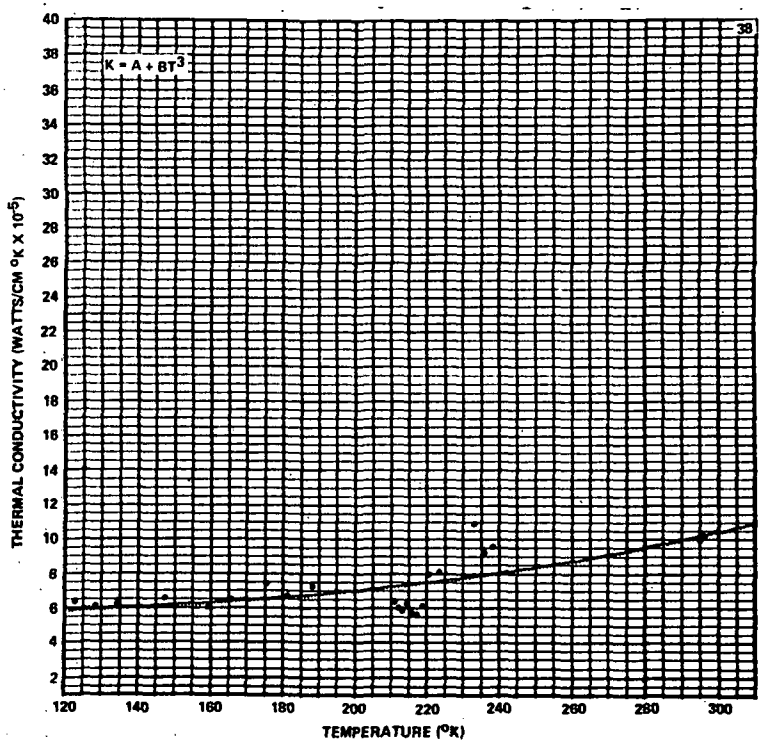


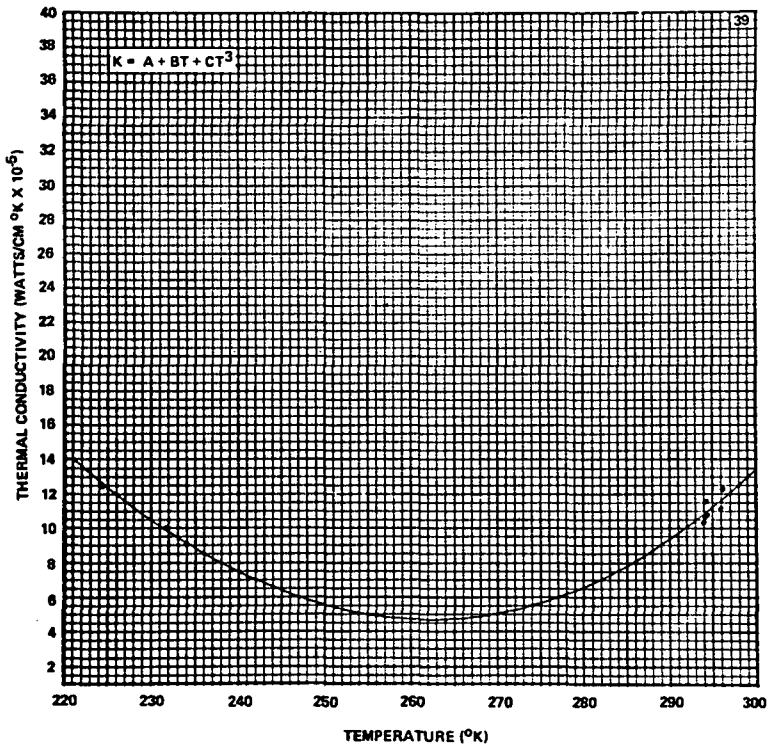
b.

SAMPLE: GLASS BEADS DENSITY: 1.51 g/cm^3 SAMPLE LOAD: 0
PARTICLE SIZE: 590-840 μm PRESSURE: 5.85 N/m^2 (N_2)

Figure 19. Thermal conductivity of glass beads as a function of temperature [density — 1.51 g/cm^3; pressure — 5.85 N/m^2 (N_2)].

TABLE 22. FIGURE 20 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
224.4	1.25
231.7	1.00
234.0	0.91
294.0	1.04
294.1	1.07
294.2	1.16
294.4	1.08
295.9	1.12
296.1	1.23



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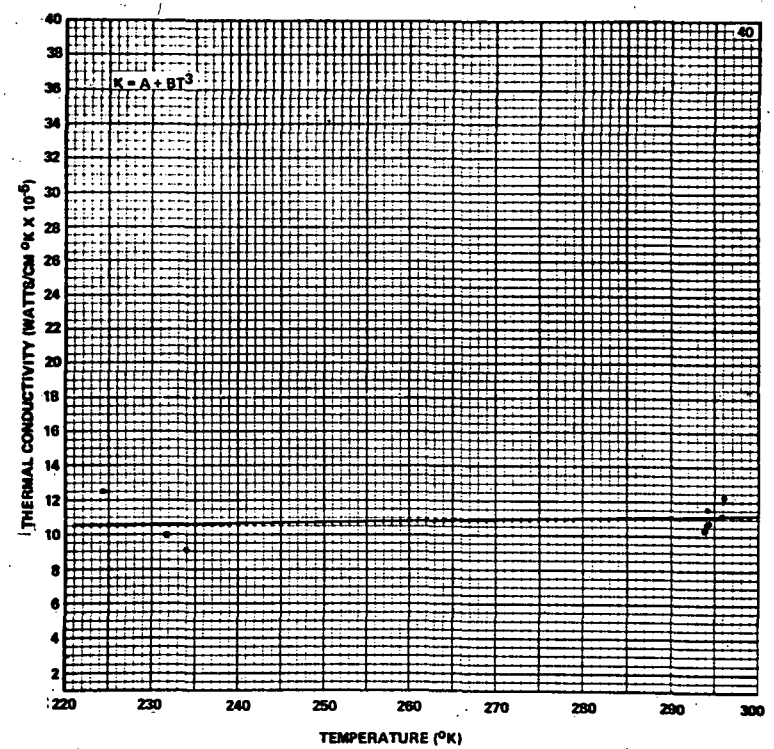


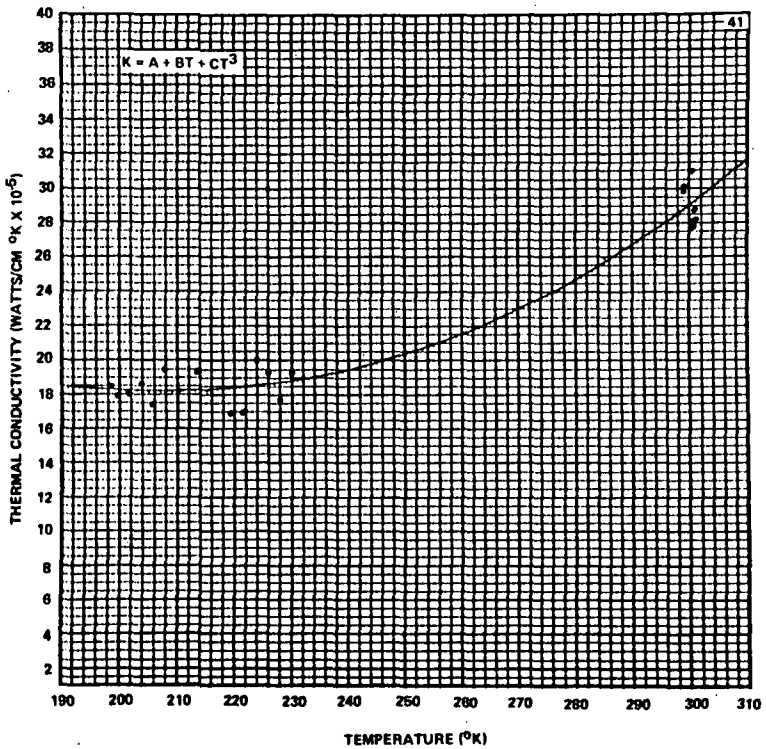
b.

SAMPLE: GLASS BEADS
PARTICLE SIZE: 590-840 μm
DENSITY: 1.58 g/cm^3
PRESSURE: 6.5 N/m^2 (N_2)
SAMPLE LOAD: 0

Figure 20. Thermal conductivity of glass beads as a function of temperature [sample load — 0; pressure — 6.5 N/m^2 (N_2)].

TABLE 23. FIGURE 21 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
198.6	1.85
199.7	1.79
201.6	1.80
203.8	1.86
205.7	1.74
207.9	1.95
210.3	1.82
213.5	1.93
215.6	1.81
219.3	1.69
221.5	1.70
224.0	2.00
226.0	1.93
228.0	1.77
230.0	1.93
299.1	2.98
299.1	3.01
300.5	2.81
300.6	3.10
300.7	2.78
300.9	2.88
301.0	2.82



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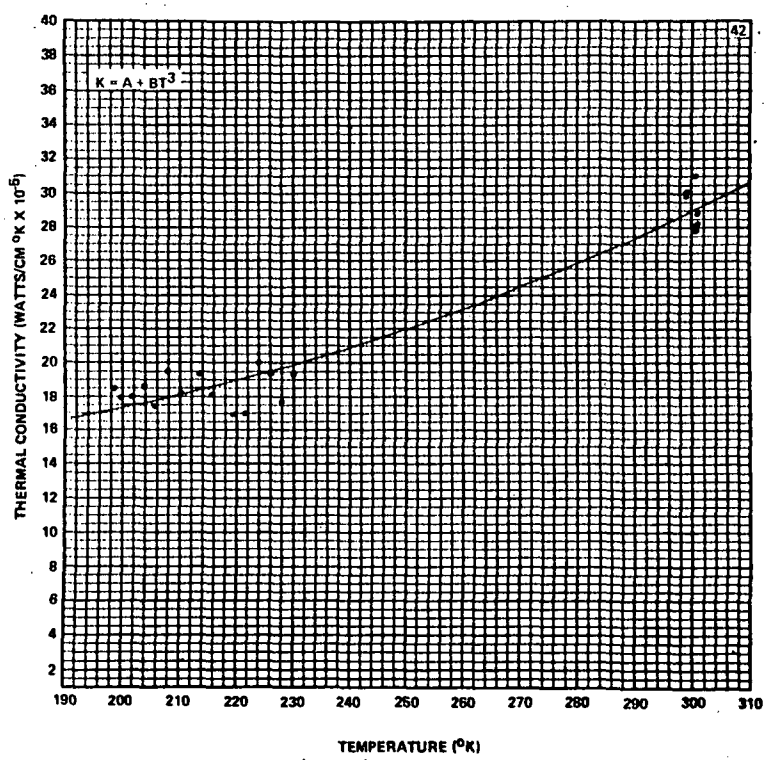


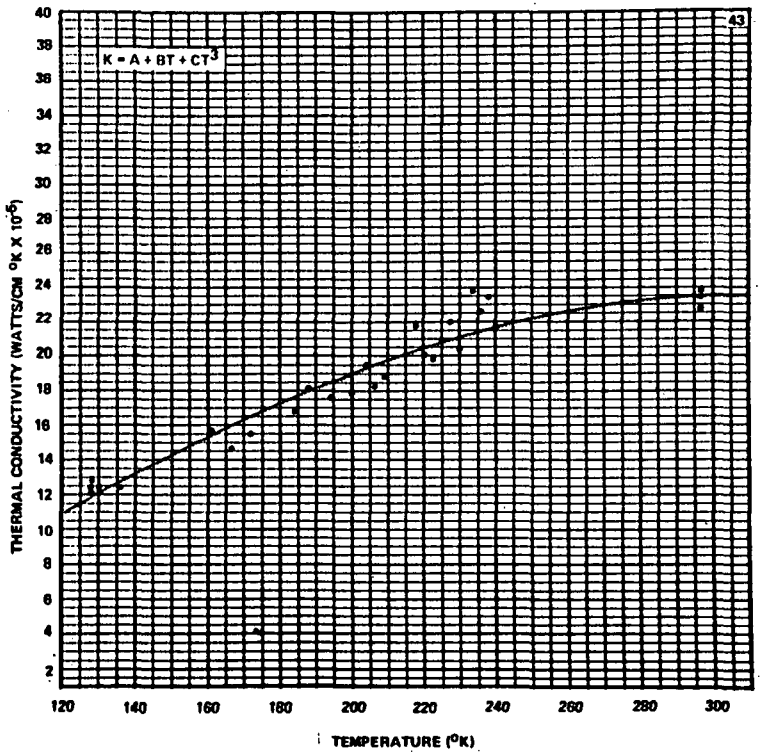
b.

SAMPLE: GLASS BEADS DENSITY: 1.58 g/cm^3 SAMPLE LOAD: 150 g/cm^2
PARTICLE SIZE: 590-840 μm PRESSURE: 6.5 N/m^2(N_2)

Figure 21. Thermal conductivity of glass beads as a function of temperature [sample load — 150 g/cm^2; density — 1.58 g/cm^3; pressure — 6.5 N/m^2 (N_2)].

TABLE 24. FIGURE 22 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
127.8	1.24
128.0	1.21
128.0	1.21
128.1	1.28
130.2	1.24
136.1	1.24
161.0	1.57
166.6	1.47
171.9	1.55
184.0	1.68
188.1	1.82
194.1	1.76
200.1	1.79
203.9	1.95
206.3	1.83
209.1	1.88
218.0	2.18
220.4	2.01
222.7	1.98
225.0	2.09
227.6	2.20
229.9	2.04
233.7	2.38
235.9	2.26
238.1	2.34
240.2	2.17
296.7	2.28
296.8	2.27
296.8	2.34
296.9	2.38



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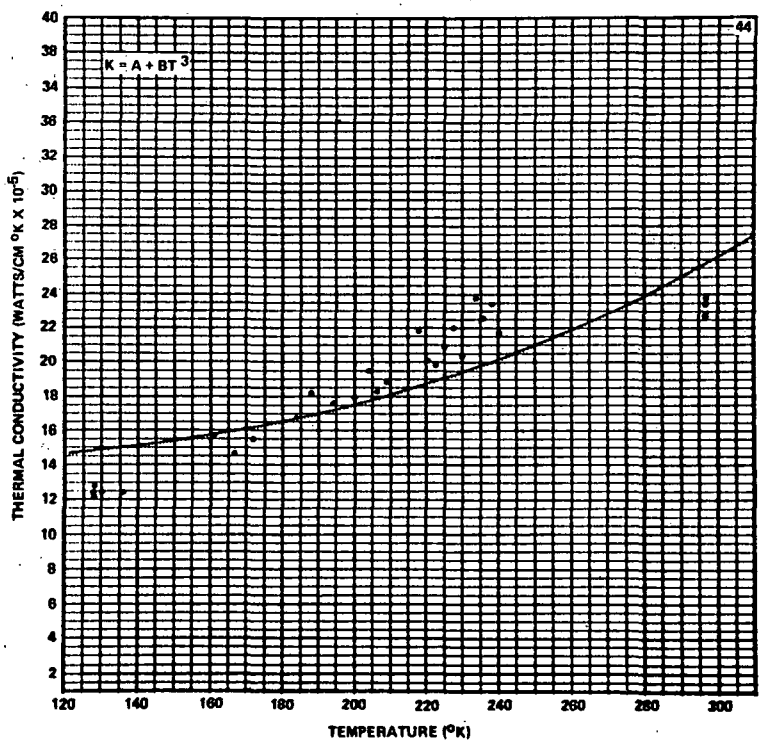


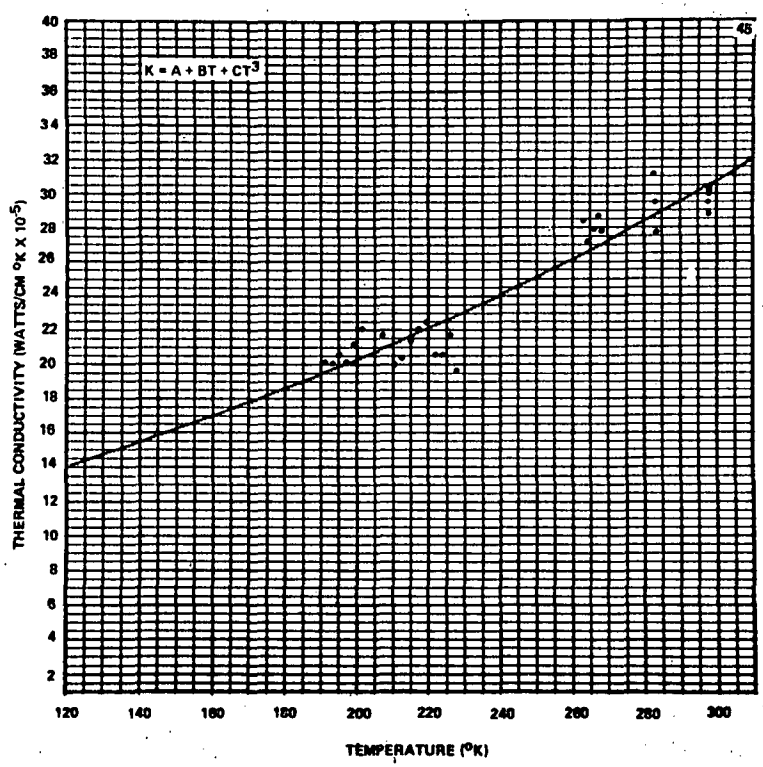
b.

SAMPLE: GLASS BEADS
PARTICLE SIZE: 590-840 μm
DENSITY: 1.58 g/cm^3
PRESSURE: 6.5 N/m^2 (N_2)
SAMPLE LOAD: 348 g/cm^2

Figure 22. Thermal conductivity of glass beads as a function of temperature [sample load — 348 g/cm^2; pressure — 6.5 N/m^2 (N_2)].

TABLE 25. FIGURE 23 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
191.2	2.02
193.3	2.01
195.2	2.06
197.0	2.02
199.1	2.12
201.4	2.21
207.2	2.17
210.5	2.00
212.5	2.04
215.0	2.14
217.2	2.21
219.3	2.25
221.8	2.06
223.9	2.06
226.0	2.17
227.8	1.97
263.2	2.84
264.2	2.72
266.2	2.79
267.3	2.87
268.4	2.78
282.5	3.12
283.1	2.95
283.5	2.77
297.7	2.95
297.8	2.88
297.9	3.00
298.0	3.02
298.1	3.03



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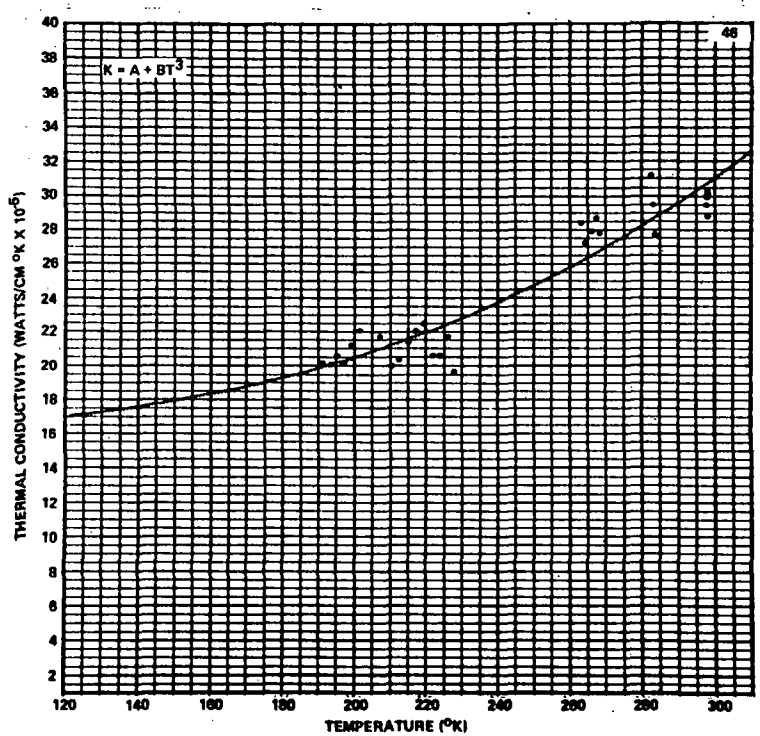

b.

SAMPLE: GLASS BEADS
PARTICLE SIZE: 590-840 μm
DENSITY: 1.58 g/cm^3
PRESSURE: 13 N/m^2 (N_2)
SAMPLE LOAD: 150 g/cm^2

Figure 23. Thermal conductivity of glass beads as a function of temperature [density — 1.54 g/cm^3; pressure — 13 N/m^2 (N_2); sample load — 150 g/cm^2].

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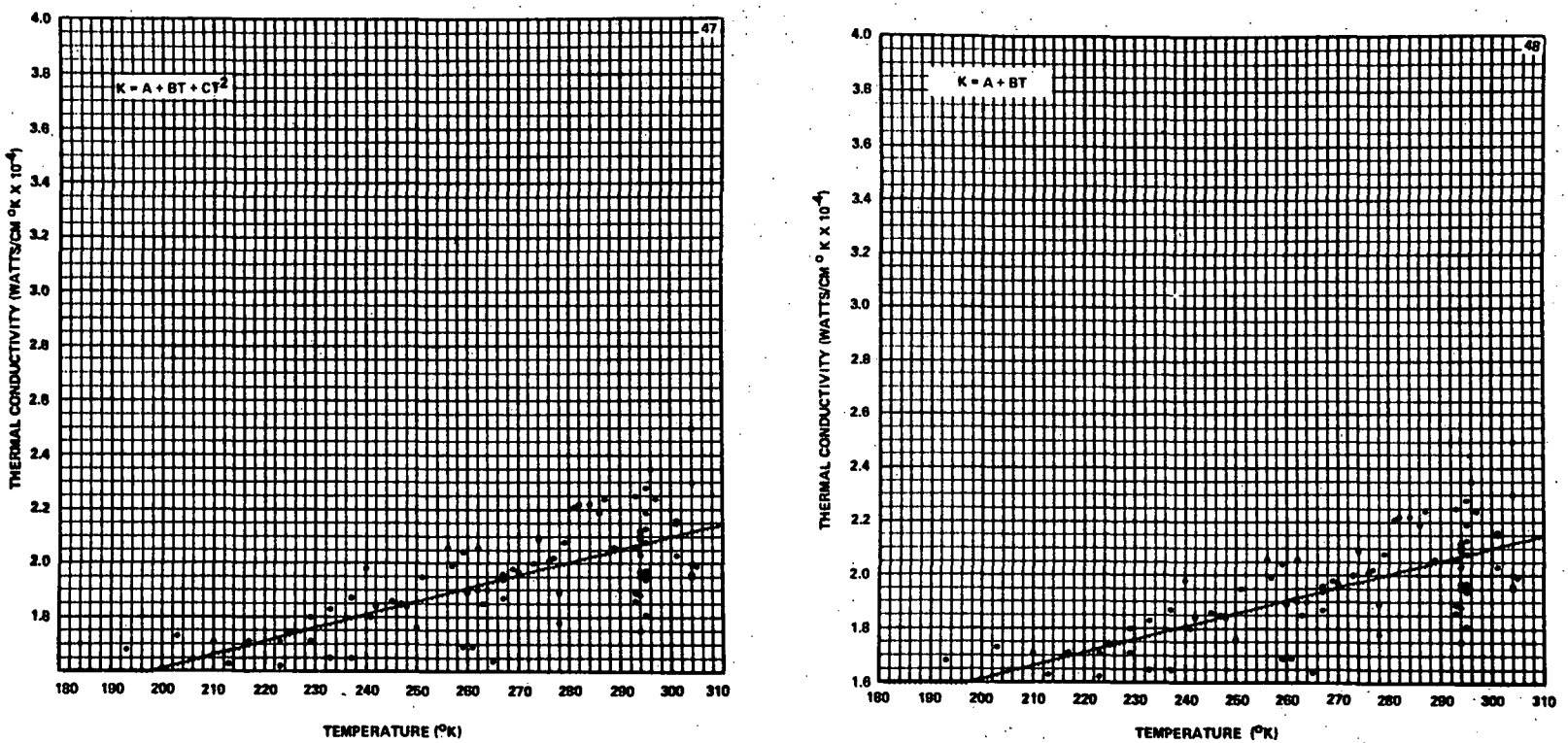
TABLE 26. FIGURE 24 DATA

Temperature (°K)	Thermal Conductivity (10^{-4} W/cm °K)	Temperature (°K)	Thermal Conductivity (10^{-4} W/cm °K)
193	1.68	256	2.06
200	1.53	257	1.99
203	1.73	259	2.04
208	1.55	259	1.69
210	1.71	260	1.89
213	1.63	261	1.69
217	1.71	262	2.06
223	1.62	262	1.90
223	1.71	263	1.85
225	1.74	264	1.90
229	1.80	265	1.64
229	1.71	267	1.94
233	1.65	267	1.87
233	1.83	267	1.96
237	1.65	269	1.98
237	1.87	270	1.97
240	1.98	273	2.00
241	1.80	274	2.09
242	1.84	276	2.01
245	1.86	277	2.02
247	1.85	278	1.89
248	1.84	278	1.78
250	1.76	279	2.08
251	1.95	281	2.21

TABLE 26. FIGURE 24 DATA (Concluded)

Temperature (°K)	Thermal Conductivity (10^{-4} W/cm °K)	Temperature (°K)	Thermal Conductivity (10^{-4} W/cm °K)
282	2.22	295	1.96
284	2.22	295	1.94
286	2.19	295	1.97
287	2.24	295	1.81
289	2.06	295	2.08
293	2.06	295	2.19
293	1.89	295	2.13
293	1.86	295	1.95
293	2.25	295	2.28
294	1.88	296	2.35
294	1.97	297	2.24
294	2.10	301	2.16
294	1.75	301	2.15
294	2.12	301	2.03
294	1.95	304	2.00
294	2.09	304	1.95
294	2.10	304	2.30
294	2.12	304	2.50
294	2.12	304	1.96
294	2.12	305	1.99
294	2.03		



SAMPLE: GLASS BEADS
PARTICLE SIZE: 30-38 μm

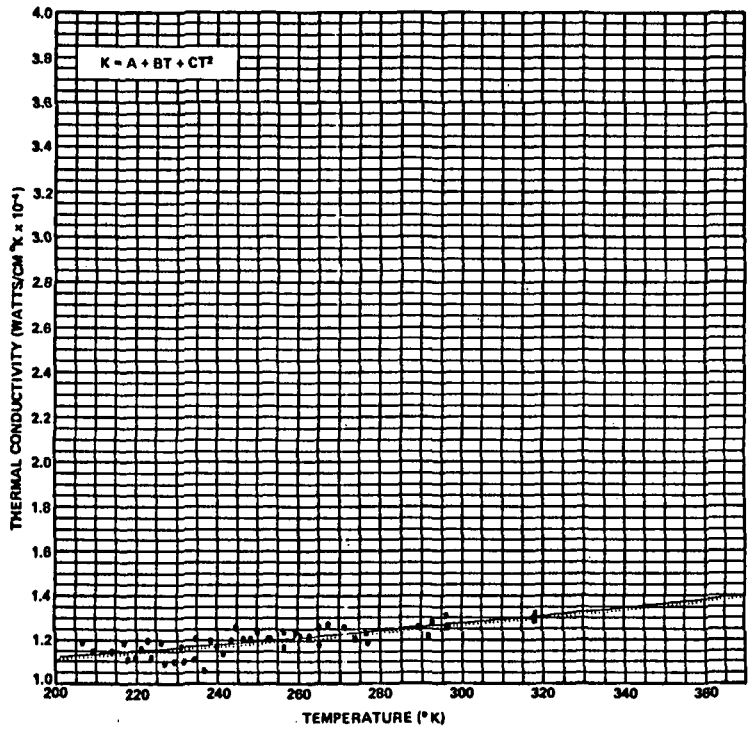
DENSITY: 1.58 g/cm^3
PRESSURE: 6.9×10^2 N/m^2 (CO_2)

SAMPLE LOAD: 0

Figure 24. Thermal conductivity of glass beads as a function of temperature (particle size — 30 to 38 μm; density — 1.58 g/cm^3).

TABLE 27. FIGURE 25 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)	Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
206.6	1.19	252.6	1.21
209.3	1.15	253.2	1.21
214.1	1.15	256.5	1.17
217.0	1.19	256.5	1.24
218.0	1.11	259.2	1.23
219.9	1.12	260.3	1.22
221.3	1.16	262.6	1.22
222.8	1.20	265.2	1.18
223.8	1.12	265.3	1.26
226.2	1.19	267.6	1.27
227.0	1.09	271.5	1.26
229.5	1.10	274.0	1.21
231.1	1.17	276.5	1.23
231.9	1.10	277.0	1.19
234.3	1.11	289.4	1.26
234.7	1.21	291.5	1.22
238.3	1.20	292.7	1.28
239.9	1.17	296.1	1.31
241.6	1.14	296.1	1.26
243.4	1.20	296.7	1.26
244.8	1.26	318.0	1.30
246.5	1.21	318.0	1.30
248.3	1.21	318.2	1.29
249.9	1.24	318.3	1.32



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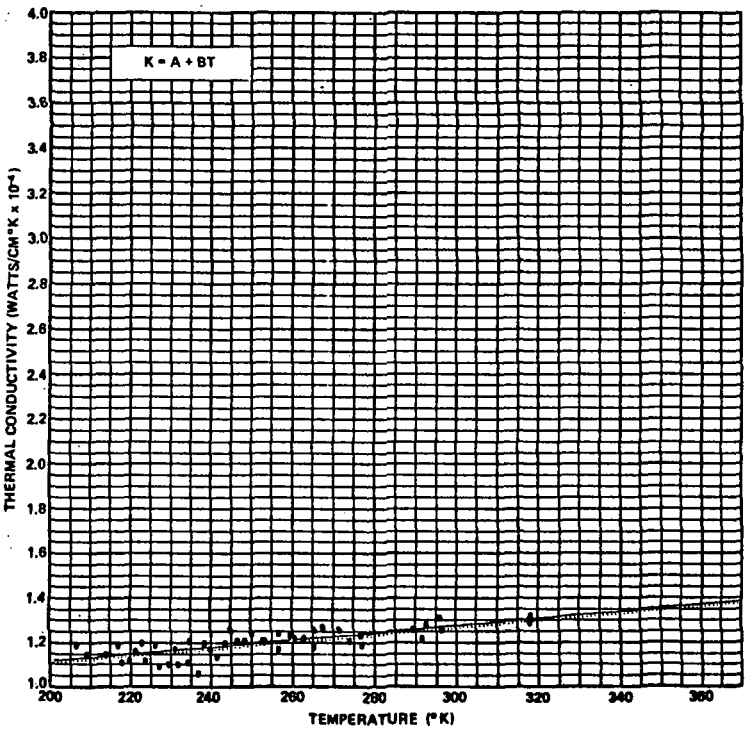


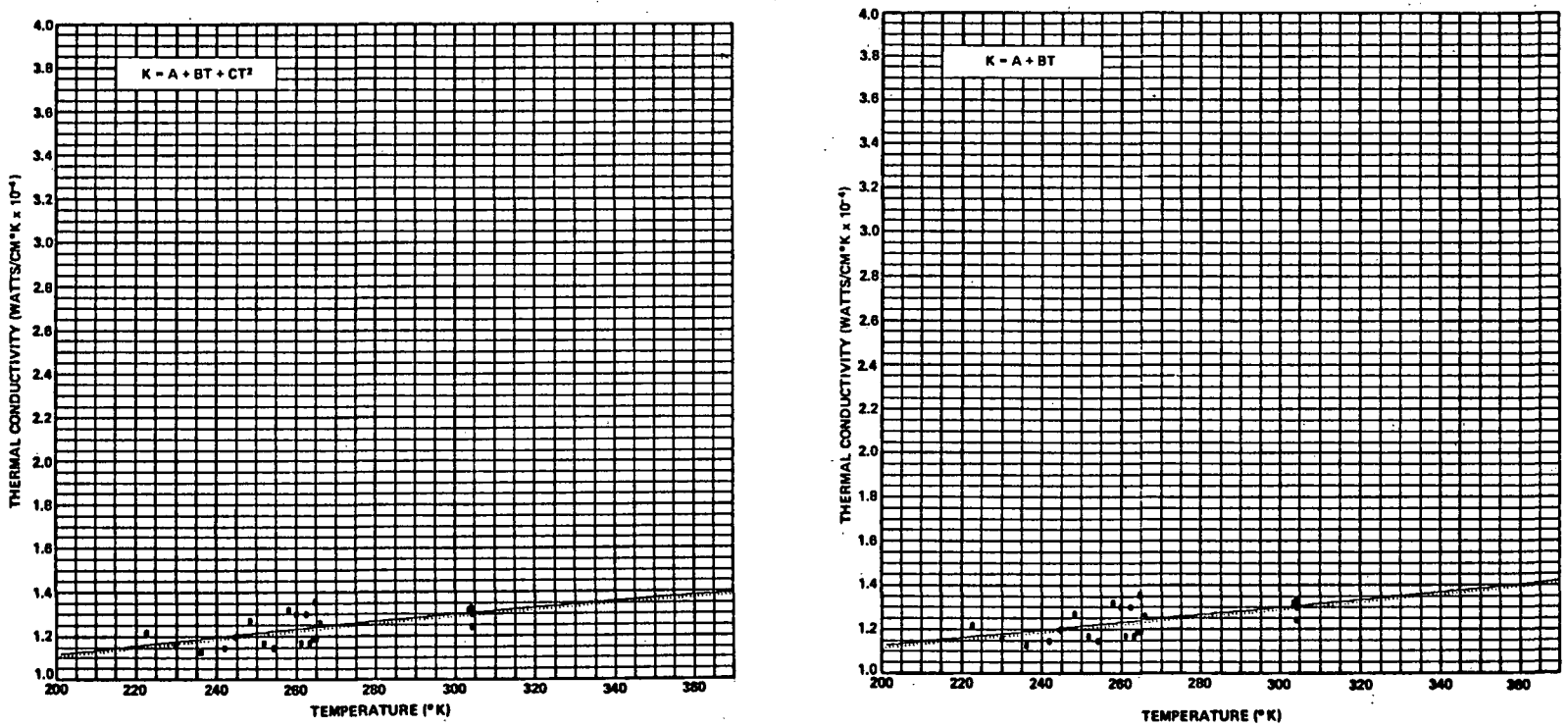
b.

SAMPLE: BASALT DENSITY: 0.79 g/cm^3 SAMPLE LOAD: 0
PARTICLE SIZE: 37-62 μm PRESSURE: 6.9×10^2 N/m^2 (CO_2)

Figure 25. Thermal conductivity of basalt as a function of temperature [density — 0.79 g/cm^3; pressure — 6.9×10^2 N/m^2 (CO_2)].

TABLE 28. FIGURE 26 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)	Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
222.6	1.22	262.4	1.30
230.0	1.16	263.4	1.17
236.2	1.13	264.2	1.19
242.1	1.15	264.8	1.36
244.9	1.20	265.2	1.19
248.4	1.27	266.0	1.26
251.9	1.17	304.1	1.33
254.4	1.15	304.2	1.32
258.0	1.32	304.2	1.24
260.0	1.30	304.2	1.30
261.2	1.17		

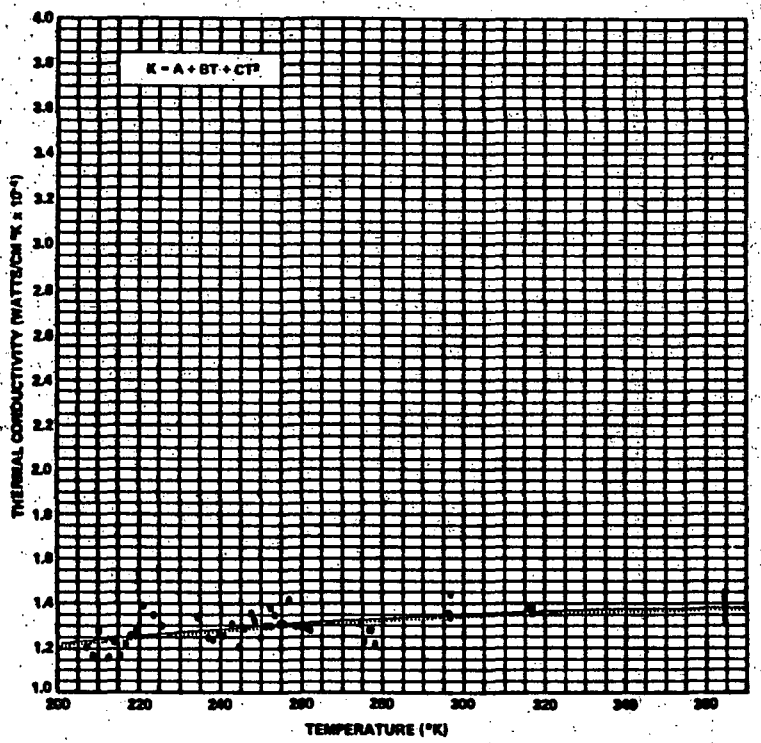


SAMPLE: BASALT
PARTICLE SIZE: 37-62 μm
DENSITY: 1.13 g/cm^3
PRESSURE: 6.9×10^2 N/m^2 (CO_2)
SAMPLE LOAD: 0

Figure 26. Thermal conductivity of basalt as a function of temperature [density — 1.13 g/cm^3; pressure — 6.9×10^2 N/m^2 (CO_2)].

TABLE 29. FIGURE 27 DATA

Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)	Temperature (°K)	Thermal Conductivity (1×10^{-4} W/cm °K)
207.2	1.21	254.5	1.31
208.8	1.17	255.6	1.31
210.2	1.28	256.8	1.42
212.6	1.16	258.4	1.30
214.1	1.23	259.9	1.30
215.4	1.17	261.2	1.29
216.6	1.22	262.2	1.28
218.0	1.26	274.6	1.31
219.4	1.28	275.6	1.23
221.1	1.39	276.5	1.28
223.5	1.35	277.3	1.28
225.6	1.30	278.1	1.22
234.3	1.34	295.9	1.36
237.0	1.25	296.3	1.36
238.2	1.24	296.6	1.34
239.6	1.27	296.7	1.34
240.7	1.26	296.9	1.44
242.7	1.31	316.1	1.38
244.6	1.21	316.6	1.36
246.0	1.29	317.0	1.36
247.6	1.36	317.0	1.38
248.3	1.33	364.5	1.33
248.6	1.32	364.5	1.38
250.0	1.25	364.5	1.43
251.1	1.30	364.6	1.37
252.2	1.30	364.7	1.32
252.2	1.38	364.8	1.45
253.4	1.35		



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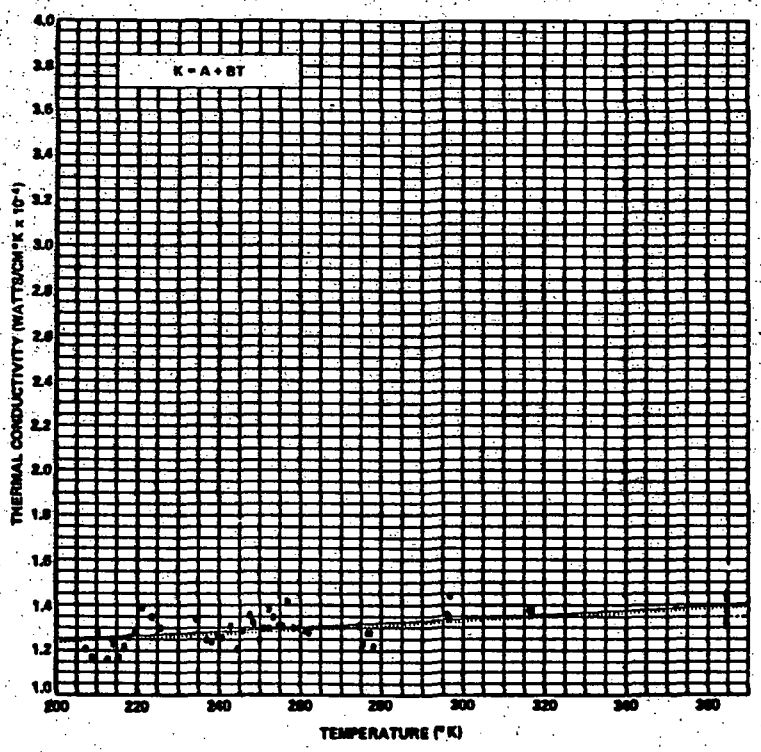

b.

SAMPLE: BASALT DENSITY: 1.50 g/cm^3 SAMPLE LOAD: 0
PARTICLE SIZE: 37-62 μm PRESSURE: 6.9×10^2 N/m^2 (CO_2)

Figure 27. Thermal conductivity of basalt as a function of temperature [density — 1.50 g/cm^3; pressure — 6.9×10^2 N/m^2 (CO_2)].

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THERMAL CONDUCTIVITY OF PARTICULATE MATERIALS: A SUMMARY OF MEASUREMENTS TAKEN AT THE MARSHALL SPACE FLIGHT CENTER

By James A. Fountain, Ronald W. Scott, and
Edward A. West

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This document has also been reviewed and approved for technical accuracy.

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